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NOVEMBER, 1953 Vol. X No. 3

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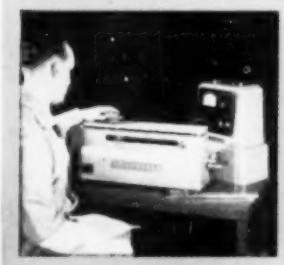

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### ENGINEERING AND PRODUCTION

Statistical quality control can and should be a vital connecting link between engineering and production. Let us see why this is so.

Initially, in the production of a new part or product, the specifications are set by design and engineering. Often such specifications have little relation to what tolerances the processes can actually hold. They are set from a more or less clear idea as to what is needed to make the product serve its intended purpose. Now production begins.

In a plant where SQC is well installed, control charts will immediately be run on all important characteristics of the product. An attempt will be made to get into control those characteristics which are not in control. This of course is much more important where the product is not meeting specifications than where it is, but even in the latter case it is desirable, so as to determine process capabilities. We simply do not know what tolerances can be met until a process is brought into control, because the very job of finding and eliminating assignable causes will usually enable a process to meet closer tolerances than it could when out of control. In this way, then, production and SQC working together will determine all the process capabilities.

As these process capabilities ($\bar{R}/d_2 = \sigma'$, "natural tolerance" = $6\sigma'$ and $\bar{\bar{x}}$ becomes $\bar{x}'$) are determined, they are continuously fed back to engineering. If the natural tolerance of a process is larger than that specified, then it may in some cases be possible for engineering to relax the specifications somewhat, especially if it can be shown that product outside will function sufficiently well. But if this is not possible, then some radical change, perhaps to a more expensive machine or material, or the inclusion of an extra operation is needed. Or 100 percent sorting must be employed. Since both of these alternatives are expensive, engineering will only require them if really necessary. There should be much advantage to engineering to know that process capabilities are only sent in when production has done "all it can" by getting good control. Knowing the extra cost of maintaining such specifications closer than the process can meet, engineering will only retain them if vital to the functioning of the product.

It may also work the other way, although this is rare. If production learns that it can readily meet considerably closer tolerances than specified, this information may permit engineering to change to closer specifications than originally set, thereby permitting improved quality, such as longer life, or a more favorable competitive position.

This back and forth exchange of information can make the relation between production and engineering much more realistic and economically sound. The foregoing is a brief sketch, but the general outline is clear. —*I. W. Burr*

### OUR COVER

This month's cover was sent in by Paul E. Allen, director of quality control, Beech Aircraft Corp., Wichita, Kansas.

It is with their kind permission that we reproduce the sentiment of this poster here.

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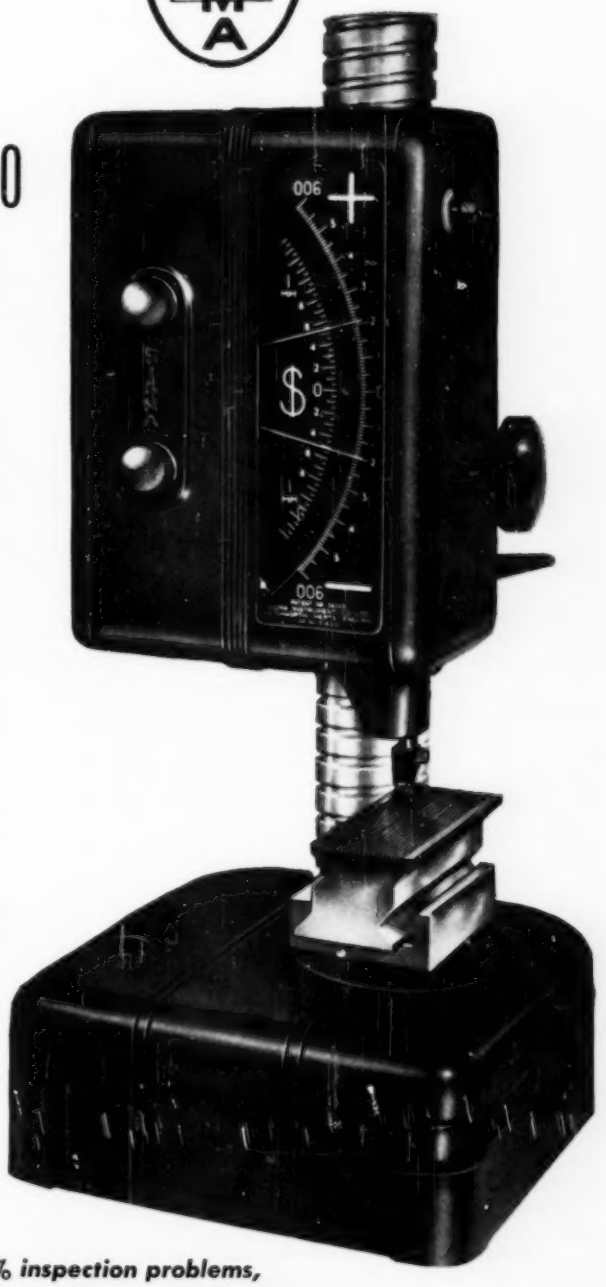


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# Some Problems in Sampling Accounting Records*

HOWARD L. JONES

Illinois Bell Telephone Company

## PURPOSE OF SAMPLING

When we sample accounting records, or business records of any kind, we usually have one of these purposes in mind:

1. To get information that is available from the records but that is not ordinarily summarized
2. To supply a framework for making some kind of survey
3. To provide a basis for testing the accuracy of the information shown on the records

An illustration of sampling with the first purpose—to obtain information not ordinarily summarized—is the sampling of our customers' accounts to determine their local telephone usage. For most of our customers in the city of Chicago, there is a tabulating card that shows the monthly usage of local service, and the charge for such service. We need to know this average monthly usage for customers in each rate classification, and the distribution of that usage; that is, the proportion of our customers that use 0-10 messages per month, the proportion using 11-20 messages and so on. It would be very expensive to summarize this information 100 percent; and so for about 25 years, we have been relying on sampling procedures.

Samples with the second purpose mentioned—to supply a framework for some kind of survey—are taken periodically in connection with our attempts to measure the attitude of our customers toward the telephone company, particularly toward the service we furnish and the charges we bill for it. Accounting or plant records, and sometimes telephone directories, are used to select the sample customers. These customers are then interviewed, by telephone or otherwise, and asked to give answers to a set of questions. The analysis and summarization of these answers yields the information we want. Similar surveys have been taken to measure the attitudes of supervisory employees toward the Company and higher management.

Another kind of sampling we do occasionally is of particular interest to engineering statisticians. This is the sampling of our plant records and engineering records to provide a framework for appraising the percent condition of our telephone property. This is one of the things we ask the regulatory commissions to take into account in fixing the rates we charge for telephone service.

The third purpose of sampling our records—to test the accuracy of the records themselves—is essentially the same as when sampling inspection is employed in a factory. We call it sampling verification; and several accounting operations are regularly inspected under single or sequential sampling plans. It is my personal opinion that we have hardly begun to utilize the tremendous possibilities in these various quality control techniques in all phases of the telephone business.

## METHODS OF SELECTING THE SAMPLE

Samples can also be grouped into about three different classifications according to the general techniques used to select the individual items that make up the sample. These general techniques are

1. Judgment sampling
2. Systematic sampling
3. Random sampling

In judgment sampling, the particular items that make up the sample are determined by some one who is supposed to be familiar with the population in which we are interested and to be able to use good judgment in selecting the items that are to constitute the sample. In systematic sampling, we start with a particular item at one end of a population that has previously been arranged in some kind of sequence, and we choose every n-th item—for example, every 10th item if we want a ten percent sample, or every 100th item if we want a one percent sample. In random sampling the sample items are selected in such manner that all items in the population have equal chances of being included in the sample, and the inclusion or exclusion of one item has no bearing on the chances of the other items.

Each of these three methods of sampling has certain advantages and disadvantages as compared with the other two methods; and no one of them is invariably the best method to use. Judgment samples are frequently necessary when we need data in a hurry, or when we are interested in only a part of a population. For example, you would not inspect manufactured parts by taking a random sample of all their dimensions. You would inspect only those dimensions that are most important. Similarly, in verifying clerical work we look for types of errors that cause the most trouble; and we pay more attention to new employees than to those with more experience. But a judgment sample is no better than the judgment of the person who designates the items to be selected. And different persons may get widely different answers to the same question.

Systematic sampling, where every n-th item is selected, is easy to explain and to supervise. Moreover, if the first item is chosen at random from the first n items in the population, the element of personal bias in the selection will be eliminated. It usually has certain other advantages. Thus, if records of telephone poles are numbered according to geographical location, a systematic sample of these records will have the correct

* The material in this article was taken largely from a paper presented at a conference on Business Applications of Statistical Methods under the joint sponsorship of the University of Illinois and the Chicago and Urbana Chapter of the ASA, Allerton Park, Monticello, Illinois, May 1950, and later at the Sixth Annual Convention, ASQC, Syracuse, N.Y., May 1952.

proportions of poles from each geographical area, or very nearly so. On the other hand, the sample measurements may not be at all representative if there are repeated cycles in the property we are trying to measure. Suppose, for example, we were to try to measure telephone usage on the basis of a sample of every hundredth telephone number. It happens that telephone numbers ending in 00 are usually assigned to customers with large private switchboards, while other numbers are assigned to these customers less frequently. For this reason, if our sample happened to include only telephone numbers ending in 00, the average usage of our sample customers would be much higher than if it included only numbers ending in 58, for example.

The chief advantages of random sampling are (1) that the sample measurements will tend to agree with the measurements for the population as a whole, and (2) that the extent of this agreement, which we call the precision of the sample, can be estimated from the sample itself. This kind of sampling is best to use where the results are to be offered in evidence before a court or a regulatory body. It can also be used in many situations where data are gathered for administrative purposes. And it is necessary to use it in investigations where the theory of probability is called into play to test some hypothesis about the population sampled. We are coming to use it more and more in our business.

## HOW TO SELECT A RANDOM SAMPLE

Random sampling would probably be used more widely if more people knew how to go about it. The necessary steps might be outlined as follows:

1. Decide on the units into which the population is to be divided for sampling purposes
2. Number these sampling units
3. Make the selection by referring to a table of random numbers
4. Count or measure the sampling units that correspond to the random numbers

The choice of sampling unit will depend on what we are interested in knowing, and on what records are available. To take a concrete example, let us assume that we wish to find out the average number of local calls per telephone subscriber per month. To select our sample subscribers, we might use any one of several records, among which are the following:

Accounting department records of service and equipment

Address plates used in preparing bills

Bill stub files in the accounting department or in the business offices

Plant department records of equipment

Traffic department records of subscriber lines

Telephone directories

Or, we might select our sample without even referring to records, as by selecting jacks on the switchboards, or by simply picking telephone numbers at random.

Now, let us turn to the problem of numbering our sampling units. In the case of telephone customers, the problem is easily solved, since our customers are already numbered. In Chicago, we reach another telephone by dialing two letters and then five digits. But since each letter dialed corresponds to a digit, as you can see by looking at one of the dials, we have the equivalent of a 7-digit numbering system. In effect, then, each customer has a number somewhere from 0 to 9,999,999, inclusive. Since there are only about 900,000 numbers actually in use, it is obvious that about 91 percent of the 10 million possible numbers actually do not correspond to telephone customers. This is not too important, however. But there is a problem due to the fact that some customers have more than one telephone number. We shall consider it later. The important considerations are (1) that each number identifies a particular customer without any possible ambiguity, and (2) that the record of local usage corresponding to a particular number can readily be located.

Suppose our customers were not already numbered. It would be quite a job to go through our records and write down a serial number for every customer. But this would not be necessary. Assume that we wish to use a file of card records, one to a customer. Suppose these cards are kept in drawers, arranged in 100 tiers with eight drawers per tier; and that no single drawer can possibly hold more than 2,000 cards. We could then assign each card a 7-digit number, letting the first two digits denote the tier, numbered left to right in some predetermined manner with 00 denoting the 100th tier; letting the third digit denote the drawer in a particular tier, counting down from the top; and letting the last four digits denote the card in a particular drawer, counting from the front. Given any particular number of seven digits or less, it would be possible to locate the corresponding card record in a few minutes, with no confusion as to which card is the right one. There would not be a card, or even a drawer, corresponding to every 7-digit number, of course; but again, this is not important.

In most sampling problems, there is some fairly simple way to number the population to be sampled.

The next step in our procedure is to select the random numbers. Tables of random digits are usually published in blocks of five or ten digits each. To select a set of 7-digit numbers, we turn to some page and block of numbers in a haphazard manner, and then begin writing down digits, seven at a time, in the order in which we find them in the table. In doing this, we may proceed horizontally, or vertically, or even diagonally across the page. When we come to the end of one page, we begin with the following page; and if we use up the last page of numbers, we start on the first page in the table. No problem is involved here unless we use up all the pages, in which case we shall have to turn to a new table to obtain our quota of random numbers.

The last step is to find the card records that correspond to the random numbers written down. This procedure is usually facilitated if the random numbers themselves have been recorded on small 3 x 5 in. cards, and then arranged in numerical sequence. In many cases, of course, we shall have a random number for which there is no card record in the population we are sampling. In every such case, the random number must be discarded completely. In no case should some adjacent record or number be substituted for the record that is missing. Because of this discarding, it will usually be necessary to select more random numbers than the number of records we require in the sample.

Now we can turn to the problem of what to do when an individual has more than one telephone number. In such cases, it is necessary to adopt some arbitrary rule beforehand so that each such individual is particularly identified with just one of these numbers. Thus, each telephone customer having more than one telephone number has what is called a "key" number, which is usually the only one that appears in the telephone directory. Suppose we identify customers in this category with their key numbers. We can then adopt the arbitrary rule that one of these customers will be included in the sample only if a random number is selected that corresponds to his key number. In this way, each customer will have just one chance of being included in the sample. Unless some such rule is adopted, customers with more than one number will have more chances of being drawn into the sample than customers with only one number. This rule, of course, will also tend to result in discarding some of the random numbers selected.

## SOME USEFUL FORMULAS

Before selecting the random numbers, we may wish to know how many we need to write down so that after discarding unusable numbers we shall be reasonably sure to have enough left to give us a sample of some specified size. A formula for this appears as Appendix A to this article.

Other formulas that have been found useful are also given there. Included are formulas for testing the distribution of the sample among the various parts of the population when the distribution of the population among these parts is known. Some such test should always be made wherever possible.

## USAGE CARDS WITH RANDOM NUMBERS

There are also some relatively new ideas that may prove useful. One of these is a suggestion made by Professor John W. Tukey of Princeton University. His idea is to punch a three-digit random number in each IBM card on which we record customers' usage. This random number would be permanently associated with the telephone number, and would be reproduced from month to month along with the telephone number when each month's card file is established. A sample of almost any size could then be selected by machine sorting on these random digits. For example, if we wanted to select a random sample to include one percent of our customers, we would select a two-digit number from a random number table and machine sort on those two digits.

## EXTREME FLUCTUATIONS

Another idea has to do with the verification of the usage records of our IBM tabulating cards. The meter readings are subtracted and the charges for the additional local message units are computed by what is known as a Type 604 electronic calculating punch. But before issuing our bills, we like to investigate cases where there are extreme fluctuations in the usage so that we can detect possible errors.

Now it happens that the Type 604 machine can indicate these extreme fluctuations automatically. Each tabulating card shows the usage for the previous month as well as the usage for the current month; and the machine will compare these two usages and select the lower usage. Let x represent the lower usage, and y the higher usage, for the last two consecutive months. The machine will multiply x by a constant, b, add another constant, a, and punch a hole in the card unless y is less than $a + bx$. This hole causes an asterisk to appear opposite the usage when it's printed, and warns us to look for trouble. We can choose the numbers a and b, to be wired into the control panel for this operation, provided we restrict these numbers to two digits. The problem is how to choose these numbers.

In deciding what values to use for a and b, we need to consider two cases or situations where the formula will fail to accomplish what is desired:

1. Cases where the formula indicates something is wrong, but the usages recorded are actually correct.
2. Cases where there is something wrong with the usage records, but the application of the formula fails to reveal it.

Cases of the second kind, if not detected, will lead to incorrect billing for telephone service, and possible irritation to customers. Cases of the first kind will lead to a waste of time and money in looking for errors that actually do not exist. So far as possible both kinds of cases, where the formula fails to perform as desired, should be kept at a minimum. In practice, however, a combination of values of a and b that tends to eliminate most of the failures of one kind will lead to a large number of failures of the other kind. Some compromise has to be made, after taking into account the relative importance of the two kinds of failure. The problem is to find the best compromise.

## DECISION FUNCTIONS

Problems similar to this have received considerable attention from statisticians in recent years. Essentially, it is the problem of deciding whether a particular pair of values of x (the lower usage) and y (the higher usage) belongs to one or the other of two populations:

A. A population consisting of correctly recorded pairs of values of x and y.

B. A population consisting of recorded values of x and y where at least one of the two values is not correct.

Failures of the first kind described above are equivalent to errors in classifying an (x,y) pair that belongs to population A. Failures of the second kind are equivalent to errors in classifying an (x,y) pair that belongs to population B. The problem is to minimize the weighted sum of these errors, where the weights are selected to correspond to the relative importance of the two kinds of errors. Two general approaches to the solution of the problem have been suggested for two different situations with respect to the information available.

The first approach can be used where information has been obtained, from study data or otherwise, as to the joint distribution of the x's and y's in each population — that is, as to the proportion of each population that corresponds with each pair of x and y. Suppose we know this proportion, and the relative importance of the two kinds of failures to classify the (x,y) pair correctly. Then it is possible, in theory at least, to find a

*decision function*, sometimes called a *discriminant function*, that will best solve the problem of classifying a particular pair of values of x and y.

The other approach to solving the problem is more suitable, if not necessary, when the distribution of population A is known or can be determined, but population B has an unknown distribution or is composed of heterogeneous elements such that any assumption about a fixed distribution would be unrealistic. This appears to be similar to the situation in many problems of quality control. In other words, when a process is in control, the variable inspected has a stable distribution; but when the process is out of control, the distribution seems to fluctuate erratically, if indeed a probability distribution can be said to exist.

The situation with respect to the problem considered here, at least at the present time, appears to be the one described for the second approach. Without attempting to give all the details involved in solving this problem, we may say in brief that we studied a sample of 10,000 usage cards to get the joint distribution of x and y for population A. Then we selected our constants a and b so that, as far as possible, the risk of deciding something is wrong when it really is not has about the same value for each x. This risk was made approximately equal to the risks in quality control when the 3-sigma limits are used in connection with $\bar{X}$-charts.

## OTHER PROBLEMS

There are many other sampling problems, of course, that have not been covered in this article. For those who wish to explore the subject further, the best procedure perhaps is to read the textbooks and periodicals in the field of statistics. A recent book that has many practical ideas is W. E. Deming's book, *Some Theory of Sampling*. It contains material that has not been available anywhere else.

### Appendix A: Determining How Many Random Numbers to Select

Suppose we wish to select a sample of size n from a population of N items. Suppose that each item in this population is assigned a serial number in such manner that no two items have the same number. It is not necessary that the largest serial number be equal to N; in other words, the largest serial number may be larger than N, and there may be serial numbers less than N that do not correspond to some item in the population.

Let

$$M = 10^d \qquad (A1)$$

where d is a positive integer so chosen that M is the smallest integral power of ten that is equal to or larger than the largest serial number. Then a random sample of the population may be obtained by selecting numbers with d digits from a table of random numbers, and observing the item with serial numbers corresponding to these random numbers, provided we assign the random number with d zeros to the population item numbered M.

Of the random numbers selected, however, only the proportion

$$p = N/M \qquad (A2)$$

will correspond to items in the population. Hence, if we select m random numbers, the usable numbers will tend to be equal to pm. To get n usable numbers, on the average, we set

$$m = n/p \qquad (A3)$$

In some cases, however, the actual number of usable numbers will turn out to be less than n/p. This may put us to the inconvenience of selecting more random numbers to get the desired sample quota. To make this unlikely, we can allow a little margin in the size of m. A simple way to do this is to set n equal to the expected value of $n_a$, the actual number of usable random numbers, plus some multiple of the standard error of $n_a$.

The average, or expected value, of $n_a$ is

$$n_a = mp. \qquad (A4)$$

Its standard error is

$$n_a = \sqrt{mpq} \qquad (A5)$$

where

$$q = 1 - p \qquad (A6)$$

Following the suggestion in the preceding paragraph, we first write

$$n = n_a + k\sqrt{mpq} \qquad (A7)$$

for arbitrary k; whence

$$m = \frac{n}{p} + \frac{k^2q}{2p}\left[1 + \sqrt{1 + 4n/(k^2q)}\right]. \qquad (A8)$$

For k = 2, this formula may be written

$$m = \frac{n}{p} + \frac{2q}{p}\left[1 + \sqrt{1 + n/q}\right]. \qquad (A9)$$

*Example*

| | |
|---|---|
| Number of telephone customers | 800,000 |
| Largest possible serial number | 9,999,999 |
| Required sample size | 1000 |

$N = 800{,}000 \qquad M = 10{,}000{,}000 \qquad d = 7$

$p = N/M = 0.08 \qquad q = 0.92 \qquad n = 1000.$

$$m = \frac{1000}{0.08} + \frac{1.84}{0.08}\left[1 + \sqrt{1 + 1000/0.92}\right]$$

$$= 12{,}500 + 782 = 13{,}282$$

### Appendix B: Stratified Sampling

The following formulas are useful when it is desired to distribute a sample over different parts, or strata, of a population so as to determine the overall mean of the population with the best possible compromise between precision and cost.

Suppose a random sample is to be selected from each of several large classes, or strata, in a population where

k = total number of classes or strata

$N_i$ — size of i - th class

$\sigma_i$ = standard deviation of i - th class

$c_i$ = sampling cost per observation for the i - th class

$c_i$ = size of sample from i - th class

$x_i$ = average, or arithmetic mean, of sample of the i - th class

$$w_i = N_i/N \tag{B1}$$

$N = N_1 + N_2 + \ldots + N_i + \ldots + N_k$ = total size of population (B2)

$$n = n_1 + n_2 + \ldots + n_i + \ldots + n_k \tag{B3}$$

$\bar{x} = w_1x_1 + w_2x_2 + \ldots + w_ix_i + \ldots + w_kx_k$ = estimated mean, or average, of the whole population of size N. (B4)

Then the total sampling cost for the n observations is

$$c = n_1c_1 + n_2c_2 + \ldots + n_ic_i + \ldots + n_kc_k. \tag{B5}$$

Also, if $\sigma_{\bar{x}}$ denotes the standard deviation of $\bar{x}$, then

$$\sigma_{\bar{x}}^2 = \frac{w_1^2\sigma_1^2}{n_1} + \frac{w_2^2\sigma_2^2}{n_2} + \ldots + \frac{w_i^2\sigma_i^2}{n_i} + \ldots + \frac{w_k^2\sigma_k^2}{n_k} \tag{B6}$$

It follows that if $\sigma_i$, $c_i$, and $w_i$ are known for each class, or can be approximated satisfactorily, we can choose $n_1, n_2, \ldots, n_k$ so that $\sigma_{\bar{x}}$ will have some specified value, $\sigma_s$, at minimum sampling cost, by employing the following formula:

$$n_i = \left(\frac{S}{\sigma_s^2}\right)\left(\frac{w_i\sigma_i}{\sqrt{c_i}}\right), \tag{B7}$$

where

$$S = w_1\sigma_1\sqrt{c_1} + w_2\sigma_2\sqrt{c_2} + \ldots + w_i\sigma_i\sqrt{c_i} + \ldots + w_k\sigma_k\sqrt{c_k}. \tag{B8}$$

Or, if we wish $\sigma_{\bar{x}}$ to be as small as possible where c, the total sampling cost, is to be some specified amount, $c_s$, we can use

$$n_i = \left(\frac{c_s}{S}\right)\left(\frac{w_i\sigma_i}{\sqrt{c_i}}\right). \tag{B9}$$

In defining $c_i$, the sampling cost per observation for the i-th class, one should usually include not only the cost of selecting the sample observation, but also the cost of inspecting or measuring, the cost of recording, and any other incidental cost one may wish to take into consideration. This cost may be expressed in money, in man-hours, or as a percentage or index number relative to the cost for one particular class. If the sampling cost per observation is about the same for each class, each $c_i$ in formulas (B7), (B8), and (B9) may be replaced by one.

To determine or approximate $\sigma_i$, it may be necessary to take and analyze a small pilot sample. The symbol $w_i$ should be regarded as a weight indicating the relative importance of the i-th class in the entire population. For example, Eq. (B4) may be used to estimate the percent condition of a physical plant where $x_i$ is the percent condition of plant belonging to the i-th class and $w_i$ is the relative investment in that class.

The cost of stratified sampling should be compared with the cost of unstratified, or simple, sampling. Unless the possible savings is appreciable, it may be better not to stratify so that the sample distribution can be tested as outlined in Appendix E.

*Example 1*

| | Symbol | Class of Telephone Service: Business Individual Line | Residence Individual Line | Residence Party Line | Total |
|---|---|---|---|---|---|
| Class | i | 1 | 2 | 3 | |
| Size of class | $N_i$ | 100,000 | 300,000 | 600,000 | 1,000,000 |
| $N_i/N$ | $w_i$ | 0.1 | 0.3 | 0.6 | 1.0 |
| Standard dev. | $\sigma_i$ | $9.00 | $2.00 | $0.50 | |
| Sampling cost | $c_i$ | 1 | 1 | 1 | |
| Product | $w_i\sigma_i\sqrt{c_i}$ | 0.9 | 0.6 | 0.3 | 1.8 |
| Desired value of $\sigma_{\bar{x}}$ | $\sigma_s$ | | | | 0.02 |

*Computations*

$\frac{S}{\sigma_s^2} = \frac{1.8}{(0.02)^2} = 4500$

$n_1 = 0.9\ (4500) = 4050$

$n_2 = 0.6\ (4500) = 2700$

$n_3 = 0.3\ (4500) = 1350$

$n = n_1 + n_2 + n_3 = 8100$

*Check*

$(0.9)^2/4050 = 0.000200$

$(0.6)^2/2700 = 0.000133$

$(0.3)^2/1350 = 0.000067$

$0.000400$

$\sqrt{0.000400} = .02$

Note: The above data are hypothetical, and should not be interpreted as describing an actual situation.

*Example 2*

A special case arises when we wish to estimate the proportion of a stratified population that possesses some particular property, and some information is available as to how items possessing this property are likely to be distributed among the various strata. For example, suppose we wish to determine the proportion of telephones that are equipped with visual signals; and that from existing knowledge, it is thought the distribution of these signals between business and residence telephone service is as follows:

| | *Business Service* | *Residence Service* | *Total* |
|---|---|---|---|
| Total no. of telephones | 500,000 | 850,000 | 1,350,000 |
| Estimated no. equipped with visual signals | 7,335 | 765 | 8,100 |
| Estimated percent equipped with visual signals | 0.01465 | 0.00090 | 0.0060 |

Assume that we wish to select a sample sufficiently large so that the actual percent equipped with visual signals can be determined with a standard deviation of 0.0003, or 0.03 percent. Proceeding as in Example 1, we prepare the following table:

| | Symbol | Class of Service: Business | Residence | Total |
|---|---|---|---|---|
| Class | i | 1 | 2 | |
| Size of class | $N_i$ | 500,000 | 850,000 | 1,350,000 |
| $N_i/N$ | $w_i$ | 0.3704 | 0.6296 | 1.0 |
| Standard dev.* | $\sigma_i$ | 0.120147 | 0.029986 | |
| Sampling cost | $c_i$ | 1 | 1 | |
| Product | $w_i\sigma_i\sqrt{c_i}$ | 0.04450 | 0.01888 | 0.06338 |
| Desired value of $\sigma_p$ | $\sigma_s$ | | | 0.0003 |

*Computations*

$\frac{\sigma_s^2}{S} = \frac{0.06338}{(0.0003)^2} = 704{,}200$

$n_1 = (0.04450)\ (704{,}200) = 31{,}350$

$n_2 = (0.01888)\ (704{,}200) = 13{,}300$

$n = n_1 + n_2 = 44{,}650$

*Check*

$(0.04450)^2/31{,}350 = 0.000\ 000\ 0632$

$(0.01888)^2/13{,}300 = 0.000\ 000\ 0268$

$0.000\ 000\ 0900$

$\sqrt{0.000\ 000\ 0900} = 0.0003$

*The values of $\sigma_1$ and $\sigma_2$ are obtained as follows:

$$\sigma_1 = \sqrt{(0.01465)\ (1 - 0.01465)} = 0.120147.$$
$$\sigma_2 = \sqrt{(0.00090)\ (1 - 0.00090)} = 0.029986.$$

## Appendix C: Computing the Coefficient of Variation from Stratified Sample Data

By definition, the coefficient of variation for any statistic is the ratio of its standard deviation to its mean value. It is sometimes useful in problems where the mean value of the population varies from time to time, but the coefficient of variation is known or believed to remain about the same. In the Illinois Bell Telephone Company, it has been used to test samples of customers' local usage. The average amount billed for this usage is known, and can also be computed from the sample data. If the percentage difference between the two averages exceeds three times the coefficient of variation, the sample is suspect.

If

$$\mu_i = \text{true mean of the i-th class} \qquad \text{(C1)}$$

and

$$\mu = w_1 \mu_1 + w_2 \mu_2 + \ldots + w_i \mu_i + \ldots + w_k \mu_k, \qquad \text{(C2)}$$

then the coefficient of variation of $\bar{x}$, as defined by Eq. (B4), is

$$V_{\bar{x}} = \frac{\sigma_{\bar{x}}}{\mu} \qquad \text{(C3)}$$

For large samples, it can be satisfactorily approximated by dividing the estimated value of $\sigma_{\bar{x}}$ by $\bar{x}$. The coefficient of variation of $N_{\bar{x}}$, the computed value of $N_\mu$ for the entire population, is the same as $V_{\bar{x}}$.

Suppose $V_{\bar{x}}$ has been computed from sample data for some recent year. Then if the ratio of $\sigma_i$ to $\mu_i$ is stable from year to year, $V_{\bar{x}}$ can be approximated for the current year by using the appropriate values of $w_i$ and $n_i$. If the coefficient is stable from month to month, and 1/12 of the year's sample is selected each month, the coefficient of variation of $\bar{x}$, as computed from data for t months only, is $V_{\bar{x}} \sqrt{12/t}$, where $V_{\bar{x}}$ is the coefficient for an entire year's sample mean.

*Example*

| i | 1 | 2 | 3 | Total |
|---|---|---|---|---|
| $w_i$ | 0.1 | 0.3 | 0.6 | 1.0 |
| $\sigma_i$ | \$9.00 | \$2.00 | \$0.50 | |
| $n_i$ | 4,050 | 2,700 | 1,350 | 8,100 |
| $x_i$ | \$5.50 | \$1.00 | \$0.25 | |

*Computations*

$$\frac{w_1^2\ \sigma_1^2}{n_1} = 0.000200 \qquad w_1 x_1 = 0.55$$
$$\frac{w_2^2\ \sigma_2^2}{n_2} = 0.000133 \qquad w_1 x_2 = 0.30$$
$$\frac{w_3^2\ \sigma_3^2}{n_3} = 0.000067 \qquad w_1 x_3 = 0.15$$
$$\sigma_{\bar{x}}^2 = 0.000400 \qquad \bar{x} = 1.00$$
$$\sigma_{\bar{x}} = 0.02$$
$$V_{\bar{x}} = 0.02/1.00 = 2\%.$$

Note: The above data are hypothetical, and should not be interpreted as describing an actual situation.

## Appendix D: Systematic Random Sampling

The sampling procedure outlined in this appendix, suggested by J. W. Tukey, combines some of the advantages of both random and systematic sampling. (See W. E. Deming, *Some Theory of Sampling*, pp. 96.)

Suppose it is desired to select a sample of size S from a population of N items numbered 1 to N. Then if

$$S = mn \qquad \text{(D1)}$$

where m and n are integers, each larger than one, we may select m subsamples of size n. In most problems, however, it is better to choose m, the number of subsamples, of some convenient size, say ten. We then find the smallest integer n such that $mn \geq S$, the desired sample size. The size of a particular subsample will then be equal to n if mn divides N exactly; otherwise some subsamples will be of size n and some of size (n + 1). We now find the largest integer, M, such that

$$M \leq N/n, \qquad \text{(D2)}$$

and call M the "counting interval."

A random choice is made of m numbers (either with or without replacement) from among the numbers 1 to M, inclusive. Designate the numbers a, b, c, ..., after arranging in order of size so that $a \leq b \leq c \leq \ldots$. The first subsample will then consist of the items numbered a, a + M, a + 2M, ...; the second subsample will consist of the items numbered b, b + M, b + 2M, ...; and so on.

Let $\bar{x}_i$ be the mean of the i-th subsample, then

$$\bar{x} = \frac{1}{m}\ (x_1 + x_2 + \ldots + x_i \ldots + x_m), \qquad \text{(D3)}$$

and $\bar{x}$ is an unbiased estimate of the overall mean of the population if the subsamples are all of the same size, and is approximately unbiased if the difference between the sizes of the largest and smallest subsamples is relatively small.

If the random numbers are selected with replacement (so that it is possible for two or more numbers to be the same), the standard deviation of $\bar{x}$ may be estimated from the formulas

$$\sigma_x^2 = \frac{1}{m-1} \sum_{i=1}^{m} (x_i - \bar{x})^2, \qquad \text{(D4)}$$

$$\bar{\sigma}_{\bar{x}}^2 = \frac{\sigma_x^2}{m}$$
$$= \frac{1}{m(m-1)} \sum_{i=1}^{m} (x_i - \bar{x})^2. \qquad \text{(D5)}$$

If the random numbers are sampled without replacement (so that no two numbers can be the same), the standard deviation of $\bar{x}$ can be estimated from

$$\sigma_x^2 = \left(\frac{M-1}{M}\right)\left(\frac{1}{m-1}\right) \sum_{i=1}^{m} (x_i - \bar{x})^2, \qquad \text{(D6)}$$

$$\bar{\sigma}_{\bar{x}}^2 = \left(\frac{M-m}{M-1}\right)\frac{\sigma_x^2}{m}$$
$$= \left(\frac{M-m}{M}\right)\left(\frac{1}{m(m-1)}\right) \sum_{i=1}^{m} (x_i - \bar{x})^2. \qquad \text{(D7)}$$

Formulas (D6) and (D7) are perfectly general formulas for computing unbiased estimates of $\sigma_x^2$ and $\sigma_{\bar{x}}^2$ for random samples from any finite population. For samples from a population of infinite size or from a continuous distribution, formulas (D4) and (D5) yield unbiased estimates for both sampling with replacement and sampling without replacement.

*Example*

A sample of size 1500 is to be selected from a population of 973,000 poles. This sample is to consist of ten subsamples corresponding to ten random starts. We put

$$S = 1500$$
$$N = 973{,}000$$
$$m = 10$$

Then we have

$$n = S/m = 1500/10$$
$$= 150$$

and choose the largest number M such that

$$M \leq N/n = 973{,}000/150$$
$$M = 6486$$

Our counting interval, therefore, is 6486. Deming, however, suggests that counting intervals that are multiples of two or five be avoided, as populations are frequently encountered where there are periodic variations at intervals of two, five, and multiples thereof. A good example is telephone numbers, where numbers ending in even hundreds are frequently associated with customers whose telephone usage is above average. Suppose that in this case, we choose a counting interval of 6387, which will yield a sample slightly larger than necessary.

After numbering the poles, we turn to a table of random numbers and select ten 4-digit numbers, excluding duplicates and numbers larger than 6387. An excellent table of this kind is the *Table of 105,000 Random Decimal Digits* published in May 1949, by the Interstate Commerce Commission, Bureau of Transport Economics and Statistics, Washington, D.C. Suppose the ten random numbers, after arranging in order of size, to be:

0131, 0830, 1288, 1603, 2523, 2617, 4746, 5550, 5761, and 6204.

Then the first subsample will consist of poles numbered 131, 6518, 12,905, and so on at intervals of 6387. The second subsample will consist of poles numbered 830, 7217, 13,604, and so on, again at intervals of 6387. The other eight subsamples will be selected in a similar manner.

After selecting the sample poles, the measurement of the particular property in which we are interested should be taken for each sample pole. Suppose we are sampling percent condition. Then this percentage (expressed as a number or code) should be recorded for each pole, and the average should be computed for each subsample. Suppose these averages to be

64.01, 64.77, 62.96, 63.41, 67.91, 64.85, 60.92, 68.07, 62.89, 60.80.

Designating these values as $x_1, x_2, \ldots, x_{10}$, we compute

$$\bar{x} = \frac{1}{10} \sum_{i=1}^{10} x_i = 64.06$$

Ignoring the slight difference in sample sizes, this is the sample mean, and is the estimate of the population mean in which we are interested. We also compute

$$\sum_{i=1}^{10} (x_i - \bar{x})^2 = 55.52.$$

Since duplicates were excluded in selecting the random numbers, the sampling procedure is equivalent to sampling without replacement. We may therefore employ Eqs. (D6) and (D7), with M and m taken as 6387 and 10, respectively, to obtain

$$\sigma_x^2 = \frac{6386}{6387}\left(\frac{55.52}{9}\right) = 6.17$$

$$\sigma_{\bar{x}}^2 = \frac{6377}{6387}\left[\frac{55.52}{(10)(9)}\right] = 0.616$$

**Appendix E: Chi-Square Test of Goodness of Fit**

The following test is useful to see whether the distribution of sample items among several classes differs from the known distribution of the population among these classes to a greater extent than one would expect if the difference was solely due to chance. Some such test should always be made when it is possible to do so.

Suppose that a population consists of the classes A, B, . . . , K in the known proportions $p_1, p_2, \ldots, p_k$, respectively, so that

$$p_1 + p_2 + \ldots + p_k = 1. \qquad \text{(E1)}$$

Then in a sample of size n, we should expect the sample frequencies for the various classes to be approximately

$$p_1 n, p_2 n, \ldots, p_k n. \qquad \text{(E2)}$$

Suppose the actual sample frequencies for these classes to be

$$f_1, f_2, \ldots, f_k, \qquad \text{(E3)}$$

so that

$$f_1 + f_2 + \ldots + f_k = n. \qquad \text{(E4)}$$

Then we can test the sample distribution to see whether it is unusual or not by computing

$$\chi^2 = \frac{(f_1 - p_1 n)^2}{p_1 n} + \frac{(f_1 - p_1 n)^2}{p_1 n} + \ldots + \frac{(f_k - p_k n)^2}{p_k n}, \qquad \text{(E5)}$$

and compare with tabulated values of $\chi^2$ for $(k - 1)$ degrees of freedom.

*Example*

A sample of 339 manholes was inspected to determine the percent condition of underground plant. Among these sample manholes, 136 were of type A, 94 of type B, 46 of type X, and 63 of other types. From plant records, it is known that the sample was selected from a total in which 38.2 percent were of type A, 27.8 percent of type B, 15.4 percent of type X, and 18.6 percent of other types. The problem is to determine whether the sample distribution was unusual.

*Computations*

| Type | p | pn | f | $(f - pn)^2$ | $(f - pn)^2/pn$ |
|---|---|---|---|---|---|
| A | 0.382 | 129.5 | 136 | 42.25 | 0.326 |
| B | 0.278 | 94.2 | 94 | 0.04 | 0.001 |
| X | 0.154 | 52.2 | 46 | 38.44 | 0.736 |
| All other | 0.186 | 63.1 | 63 | 0.01 | 0.000 |
| Totals | 1.000 | 339 | 339 | | 1.063 |

Therefore

$$\chi^2 = 1.063$$
$$k - 1 = 3$$

Turning to a table of $\chi^2$ for three degrees of freedom, we see that the entry corresponding to n = 3 and P = 0.80 is 1.005. Hence, samples with values of $\chi^2$ as large as in the sample actually taken would be expected to occur almost 80 percent of the time. We therefore conclude that the difference between the sample frequencies and the expected frequencies are not unusual, and that so far as this test is concerned, there is nothing to indicate that the sampling procedure is not satisfactory.

### Appendix F: Table of Auditor's Risks

The following table shows the risk of not detecting at least one of 1, 2, . . . , 8 discrepancies in a cashier's accounts if a random sample is taken covering 2, 4, . . . , 20 percent of the total of a large number of accounts of one or more cashiers. Thus, the last entry in the column headed "1" means that if there is just one discrepancy in all the accounts, a 20 percent sample selected at random will have 80 chances out of 100 of not including that particular discrepancy.

If the sample is not selected at random, but is selected by taking a whole tray of address plates here and there, for example, the risks may be different from those shown in the table for more than two discrepancies, unless these discrepancies themselves are distributed in a random fashion.

| Sample Percent | Number of Discrepancies | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 2 | .98 | .96 | .94 | .92 | .90 | .89 | .87 | .85 |
| 4 | .96 | .92 | .88 | .85 | .82 | .78 | .75 | .72 |
| 6 | .94 | .88 | .83 | .78 | .73 | .69 | .65 | .61 |
| 8 | .92 | .85 | .78 | .72 | .66 | .61 | .56 | .51 |
| 10 | .90 | .81 | .73 | .66 | .59 | .53 | .48 | .43 |
| 12 | .88 | .77 | .68 | .60 | .53 | .46 | .41 | .36 |
| 14 | .86 | .74 | .64 | .55 | .47 | .40 | .35 | .30 |
| 16 | .84 | .71 | .59 | .50 | .42 | .35 | .30 | .25 |
| 18 | .82 | .67 | .55 | .45 | .37 | .30 | .25 | .20 |
| 20 | .80 | .64 | .51 | .41 | .33 | .26 | .21 | .17 |

The formula for computing the above table is simply

$$R = (1 - P)^d \qquad \text{(F1)}$$

where P is the sample percentage (expressed as a fraction), d is the number of discrepancies, and R is the risk of not detecting at least one of the discrepancies present.

# The Quality Control Engineer In the Pulp and Paper Industry*

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## INTRODUCTION

In its broad sense, quality control is the prevention of defective manufacture, whatever methods may be used for that prevention. From this viewpoint, quality control in the pulp and paper industry, though usually not known by that name in the past, is as old as the industry itself. For years inspections and measurements have been made on materials, at various process stages, and on finished products. For years such inspections and measurements have of necessity been made on a sampling basis. For years the data from these inspections and measurements have been used to determine what process adjustments should be made to prevent defective manufacture. From this standpoint, any company which is competing successfully in the industry today must have had quality control from the time it started its manufacturing operations, otherwise it could not compete successfully.

It is generally recognized today, however, that to continue to compete successfully in the future, "Quality Control" in the old sense is not enough; there must be a "Quality Control Program," recognized as a separate service function. The difference between quality control in the old sense and a quality control program in the modern meaning is that the latter not only attacks day-to-day problems as they arise, but is also a coordinated service function for long-term planning. This coordination and long-term planning call for the use of certain managerial and technical skills. These skills are the basis of the Modern Quality Control movement.

The purpose of a quality control program is to minimize losses due to defective manufacture. There are two general categories into which these losses fall. One is loss of good will as a result of defective product which finds its way to the customer. The other is excessive internal costs incurred to prevent this from happening, such as high rates of scrap and rework, downgrading of product, and excessive inspection costs.

In the pulp and paper industry the potential value of a quality control program is large. The market is extremely conscious of quality, and, as a result, internal losses incurred in trying to meet market quality are high. In addition to the many day-to-day problems, there is a gold mine of long-term process control problems to which a quality control program may be dedicated.

To gather information on the present status of and thinking about quality control in the pulp and paper industry, a survey of the field has recently been started. The purpose of the survey is two-fold. One objective is to clarify just what is meant by a quality control program in the industry, and how it can best be organized. The second objective is to indicate the types of contributions the quality control engineer can make to the progress of the program. While the information gathered so far is comparatively meager, certain outlines are beginning to emerge. These outlines, as they appear

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†Mr. Purcell is now with Rath & Strong, Inc., Boston, Mass.

at present, can be illustrated by describing the situation at a mythical, idealized, composite company called Quality Pulp and Paper, Inc.

## TYPICAL QC ORGANIZATION

Quality Pulp and Paper is a multi-plant organization with pulp mills and paper mills. At each mill there is an inspection group headed by a quality control supervisor. There is a central quality control office occupied by the quality control manager and several quality control engineers. The quality control supervisors and quality control engineers report to the quality control manager, who in turn reports to the vice president in charge of manufacturing.

One important duty of the QC supervisor is to appraise the quality of the finished products shipped from the mill to which he is assigned. He keeps the QC manager continually informed of the results of such appraisals. The QC manager analyzes and condenses these appraisals, studies trends and pertinent data on customer complaints, conducts market quality surveys, etc. From such data he assembles each month a Product Quality Audit for the vice president. In addition, any serious quality deviations are reported immediately from the QC supervisor to the QC manager to the vice president. The purpose of this part of the program is the prevention of loss of customer good will due to defective product.

In making these finished product appraisals, the QC supervisor is essentially "detecting deviations" from quality standards.

The other duties of the QC supervisor are directed toward the objective of minimizing internal losses due to defective manufacture. In carrying out these duties, he is "detecting abnormalities" in materials, processes, and finished products. Abnormalities are immediately reported to the manufacturing personnel in order that the know-how of the foremen and operators may be put to work immediately on the problem of ferreting out and eliminating the causes.

In addition to detecting abnormalities the QC supervisors at Quality Pulp and Paper are constantly improving their skills in "detecting patterns of variability." Such patterns of variability, if brought to light in the early stages, are of substantial assistance to the operating know-how in finding causes. Illustrations of abnormalities are oil spots on a continuous sheet of pulp as it leaves the last drum of a dryer, and holes in a sheet of paper as it leaves the calender stack. A pattern of variability of the former would be indicated if all of the spots observed were two to three feet from the right hand edge of the sheet. A pattern of variability of the latter would be indicated if the distances between holes observed were consistently equal to the length of the wire.*

QC supervisors and their inspectors, however, are busy people. Patterns of variability are not always readily apparent. If the QC supervisory group devotes too much attention to detecting patterns of variability in one spot, abnormalities may be missed in other spots. When this situation develops, the QC engineers are brought in to carry on the search for patterns of variability, and the quality control supervisory personnel devote such time as they can spare to assisting the QC engineers, but essentially return to their primary function of detecting deviations and abnormalities.

Thus the QC engineers at Quality Pulp and Paper are occasionally assigned to immediate problems. Most of their time, however, is devoted not to abnormalities but to chronic control problems. For instance, they develop and put into effect improvements in the specifications system; revise, where necessary, the procedures for cross-checks of testing instruments; improve methods of sampling to assure more accurate quality appraisals; assist in the planning, executing, and analyzing of experiments [1] for the study of cause and effect relationships, etc. In addition there emerge extended quality control engineering projects to help in solving the more difficult chronic control problems. In these projects also the technique of detecting patterns of variability is fundamental, and added to this is the search for new facts on relationships between cause and effect. From these new facts come improvements in the methods of controlling quality.

As illustrations, two quality control engineering projects, typical of those described in the survey, are discussed here.

## MULTI-VARI CONTROL CHART

The first typical project discussed is the development and application of a type of multi-vari control chart and log for paper machines. It is essentially an adaptation of the multi-vari chart introduced by Seder.[2] It is designed to assist the operator in controlling the quality of the paper he makes.

In running a paper machine the operator must keep a watchful eye not only to prevent defects such as holes, spots, wrinkles, etc., but also to control simultaneously several measured characteristics, such as basis weight, mullen, porosity, tensile, tear, etc. The controlling of these several measured characteristics at the same time, many of them interrelated, has become an art of which the skilled papermaker is justifiably proud. Part of his art is to know, at any given time, whether a process adjustment is required. If it is not required, he must leave the process alone. If an adjustment is required, he must know what to adjust, when to adjust it, in what direction, and how much of an adjustment to make. He must know how long it will take the result of his adjustment to affect the quality of the finished paper. He must analyze the measurement data to see whether the process is, in fact, responding to his adjustments, and, in so doing, must look for patterns of variability both in the machine direction and in the cross-machine direction.

Unfortunately papermakers are not all equally skilled. There are three kinds of evidence which attest to the truth of this. First is "proof-of-the-pudding" type of evidence; the product made by some operators is less uniform than that made by others. Second is the fact that, under very similar conditions, some operators adjust their machines more frequently than others.* Third is the startling difference between answers given by various operators to the same question. Among questions known to have been answered quite differently are:

*The "wire" of a Fourdrinier paper machine is an endless wire-mesh screen which travels over rollers in the direction of pulp flow and returns underneath the rollers. A dilute slush of pulp is fed onto the moving wire and the water drains through, leaving a sheet of matted pulp which passes on to rolls, dryers, etc. If there is a defect in the wire it will cause a recurring defect in the sheet, and the distance between defects will be equal to the length of the wire.

*The operators who adjust most frequently usually are not the ones who produce the most uniform product.

"How much does a half-turn on the stock regulator affect the basis weight?"

"How much does an increase of 10 amperes in the jordan affect porosity?"

"How long does it take the effects of these adjustments to be complete at the dry end?"

So long as such questions are without answers as told by the processes, papermaking remains an "art." The purpose of the multi-vari chart and log is to change part of this "art" to "science." As science, the facts about cause-and-effect relationships become available to all operators, rather than being "known" only by those with long experience. The multi-vari chart and log helps to effect this change by providing several services, among which are:

1. A clear picture of the pattern of variability.
2. A continuous record of the adjustments which are made.
3. A prompt and clear picture, in terms of product quality, of how the process is responding to the adjustments.
4. Limits within which the product may be considered uniform. When variation remains within such limits, no adjustments should be made.

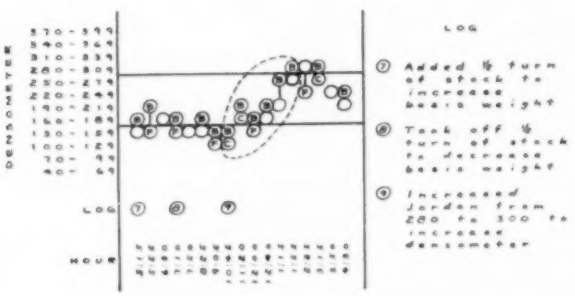


Figure 1—Multi-Vari Chart and Log

A typical multi-vari chart and log is shown in Fig. 1. Each vertical pair of circles represents the two extremes of the three measurements taken across the sheet at the end of a reel.† The letters mean front (F), center (C), and back (B). An empty circle means a tie. In the actual illustration, for instance, the first entry at 5:15 means that B was in the range 160-189, and both C and F were in the range 130-159; the second entry at 5:55 means that B was in the range 190-219, F was in the range 130-159, and C was between these two; at 6:30 all three readings were in the range 160-189.

If the distance between circles on a vertical line is too great, there is excessive cross-machine variability. If there is a repetitive pattern from reel to reel (e.g., B always high), there is a repetitive pattern in the cross-machine direction. Significant variability in the machine direction is represented by significant shifts in the levels of the circles as the chart progresses from left to right.

The log of adjustments at the right is the heart of the chart. These tell specifically what is adjusted, in what direction, how far, and for what reason. By means of the number system the adjustments are coded to the chart on the reel-to-reel time scale. Thus, over a period of time, clear data may be assembled to indicate the extent and speed of the changes in finished paper characteristics which result from specific amounts of adjustment.

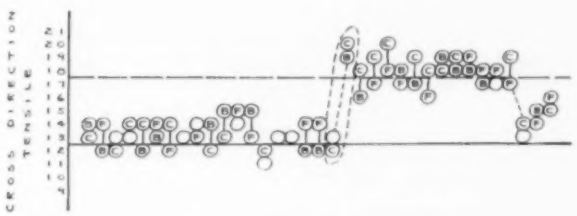


Figure 2—Repeating Cross-Machine Variability

The chart limits apply to the *individual* measurements at the three points across the sheet. In this way a single chart indicates both range and central tendency, and avoids the misunderstandings which often develop between the statistician and production man when limits are set for *averages*. While this method loses some of the sensitivity attained when averages are plotted, experience has indicated that this is not a serious practical disadvantage. To establish the limits, the three measurements across each reel are considered as a subgroup.* After eliminating those subgroups in which a significantly repetitive cross-machine pattern is observed,† the average of the ranges of the remaining subgroups is calculated. From this, the standard deviation of individual values is computed.[2] The distance between limits on the chart is six standard deviations of individual values.

In several reported instances these charts have indicated clearly the presence of repetitive cross-machine variability which had not been observed in the mass of figures of tabulated data. They have in many instances indicated that changes in flow of stock, amount of jordan treatment, etc., start trends which last for several reels rather than taking place immediately and sharply. Thus there is evidence that paper machines have been subjected to overadjustments, resulting in a saw-tooth pattern of variability from time to time. Additional knowledge on this question should be of real value to the paper maker.

Figure 2 is a reported illustration of a repeating pattern of cross-machine variability. Figure 3 is a reported illustration of a typical instance of overadjustment.

†At the dry end of the paper machine there are two rotating spindles. The finished paper is taken up on one of the spindles until enough paper has been wound to constitute a "reel" of paper. The sheet is then broken and the free end is taken up on the other spindle. Meanwhile the first reel of paper is slit and wound into rolls. Sampling at the end of each reel shoud be regarded as a periodic sampling of the continuous sheet; the reel end is simply a convenient time to cut samples because the sheet has to be broken anyway.

*The validity of using measurements across the machine as a subgroup from which to compute limits for the machine direction has been a point of controversy in the survey. The contention of those who challenge the validity of the method is that variability in the machine direction is due to causes entirely different from those affecting cross-machine variability. Those who defend the method admit that this is true as far as *dominant* (assignable) causes of variability are concerned. They point out, however, that the setting of chart limits is based on the combined effect of many *small* (chance) causes; and have submitted data indicating that these chance causes affect variability in both directions to about the same extent.

†The reason for eliminating such subgroups is to avoid erroneous inflation of the within-subgroup range. Such subgroups contain dominant causes of variability.

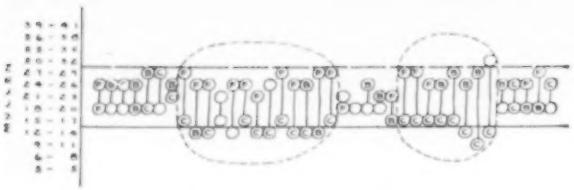

Figure 3—Overadjustment

## OPERATING CHARTS FOR CONTROL

The second typical project discussed is the development of a series of operating charts for control to help in improving uniformity of product in various process stages in the pulp mills. It is based on the technique of multiple regression.[1]

The basic questions of controlling quality are the same in the pulp mill as in any manufacturing operation. These questions, repeated again here, are:

1. Is the process in need of adjustment?
2. If so:
   - (a) When should an adjustment be made?
   - (b) What should be adjusted?
   - (c) In what direction should it be adjusted?
   - (d) How far should it be adjusted?

The answers to these questions in the pulp mill are not easy. Usually there are several factors to contend with simultaneously. A typical illustration is the ordinary chemical reaction.

Suppose, for instance, that the pulp flows continuously into a reaction tank. The chemical property to be controlled is determined by testing periodic samples of the pulp as it flows into the tank (incoming property). The object of the reaction is to raise the value of this chemical property to some desired level. How successful the reaction is in getting the property to the desired level is determined by testing periodic samples of the pulp as it flows out of the tank (outgoing property).

The four fundamental factors in such a reaction are:

(A) At what value of the property to be controlled did the pulp enter the tank? (incoming property)

(B) How long will the pulp remain in the tank?

(C) How much chemical reagent should be used?

(D) What should the reaction temperature be?

Usually factor (A) is somewhat variable; often it varies widely. Factor (B) can sometimes be controlled by the operator; more frequently it is controlled by the demands of production. Factors (C) and (D) can usually be controlled by the operator, but often with limitations dictated by the economics of the cost of reagents and heat.

To be specific assume that (A) and (B) are not controlled by the operator; i.e., that he must take these as he finds them, but that he has control, within limits, of (C) and (D). He still has a complex problem. Knowing (A) and (B), his problem is to select values of (C) and (D) which will produce a uniform product at the desired level as it flows out of the tank.

How does he go about solving his problem? As a trained chemist, he "knows" the extent to which *time, amount of reagent,* and *temperature* will affect the chemical reaction. His "knowledge" may be based on published information. Better still, his knowledge may be fortified by the results of experiments conducted in the laboratories of his own company, possibly even by himself. Yet he knows also that these laboratory results do not necessarily hold true in the "every-day pulp mill." Past data have shown him that certain departures from theoretical practice must be followed to secure the results he wants. Just what these departures are is not always entirely clear, and at best they seem to vary from time to time. Yet a study of past data seems useless in an attempt to clarify them, for the data appear to be hopelessly entangled, not only because of the entwining of the variability of the four "major" factors which have been mentioned, but also because of countless other factors which enter into the results and "cannot" be separated from the data.

Even if he could succeed in "knowing" the effects of each of the four major factors, he is pressed with the need for immediate decisions on the two over which he has control, and, in the pressure of the day's work, he would have to be almost a human computing machine to arrive at the optimum answers each hour during the day. He therefore simply does the best he can. If the result meets the quality requirements of the customer, all is well. If not, there is continual pressure for more uniform quality, but there is a dearth of constructive suggestions as to how it shall be attained.

In a situation of this kind the technique of multiple regression offers valuable assistance. The first step in this technique is to tabulate data from *mill experience*, a typical example of which is shown in Table I. In such a tabulation the outgoing property (after reaction) is matched against the *corresponding* values of incoming property (before reaction), time, amount of reagent used, and temperature. Due care is taken to allow for time of flow from one point to another.*

The multiple regression technique is a mathematical procedure for processing the data in such a way that a least-squares linear regression equation results. This equation expresses, as closely as a linear equation can, the outgoing property (P) as a function of the four "major" process variables; viz., incoming property (A), time (B), amount of reagent (C), and temperature (D)—*in each case showing the effect of one factor while mathematically holding the other three factors constant.*

In the case of the data from Table I, the regression equation is:†

$$P = 4 + 1.51A + .064B + 435C + .71D$$

In addition to providing such an equation, the multiple regression technique also provides measures of:

*This is not an easy part of the problem. Flow is complicated by pipe friction, eddies, agitation, blending, etc., which preclude sharp identification of product. Solution of this part of the problem could well be a major project to be attacked by statisticians.

†Ten values of each variable are, of course, entirely inadequate for satisfactory determination of a multiple regression equation involving four independent variables. In practice most of those reporting would use about ten similar sets of data. From each set of data a set of values for the coefficients of A, B, C, and D would be determined. Thus both the average values and the variabilities of the coefficients would be indicated. One advantage in using this technique over using one hundred values for one determination is that it tests the reproducibility of the results, which should be considered in determining practical significance.

TABLE I—Typical Data from Mill Records

| Incoming Property (A) | Reaction Time (B) | Amount of Reagent (C) | Reaction Temperature (D) | Outgoing Property (P) |
|---|---|---|---|---|
| 47 | 116 | .038 | 90 | 164 |
| 45 | 125 | .030 | 100 | 161 |
| 56 | 118 | .028 | 110 | 187 |
| 47 | 121 | .042 | 85 | 162 |
| 55 | 117 | .048 | 90 | 177 |
| 54 | 123 | .050 | 115 | 197 |
| 44 | 119 | .038 | 105 | 170 |
| 56 | 115 | .044 | 105 | 189 |
| 51 | 117 | .042 | 100 | 171 |
| 55 | 123 | .046 | 95 | 182 |

1. The amount of variability in P which remains unexplained by variability in A B, C, and D. If this is small, good control is within reach. If it is large, other dominant factors must be found before substantial improvements in uniformity can be attained.*
2. The significance of the effect of each of the tested variables (A, B, C, D) on the variability of P.

In the case of the data from Table I, only 20 percent of the variability in P remains unexplained by variability in A, B, C, D.† This is very good. Furthermore, the effect of B is without significance. This means that reaction time, within the limits to which it varies in practice, is not important‡ and need not be considered by the operator in deciding on values of C and D. Thus his problem becomes substantially simplified.¶

Even so, the operator must still take into consideration the value of A, and from this decide on a combination of values of C and D which will yield a value of P as near as possible to the desired value. This is still not easy under the pressure of hourly duties.

The decisions can be speeded and their accuracy improved, however, by an Operating Chart for Control. The first step in making such a chart is to recalculate the regression equation, leaving out of consideration the insignificant factor B. The new equation is:

$$P = 12 + 1.47A + 419C + 0.72D$$

Suppose that the desired value of P is 175. Substitute this value of P:

*Other dominant factors might be interactions between factors already considered. Such a situation calls for further extension of the multiple regression technique. For instance, see: Brownlee, K. A., *Industrial Experimentation*, Chemical Publishing Company, 1947, p. 141.

†This statement requires clarification. The coefficient of multiple correlation is

$$r = 0.98$$

From this, the standard error of estimate of P is

$$S_p = \sqrt{1 - r^2}\,\sigma_p$$
$$= 0.2\sigma_p$$

Thus the error of estimate of P is 20 percent of the standard deviation of P. This is what is meant by the statement.

‡As above, this conclusion would be based not on ten values alone, but on ten analyses of ten values each.

¶The simplification may be more fundamental and important than it seems at first glance. In one instance reported, the importance of a suspected factor had been the subject of considerable controversy. Improved control of the factor was clearly possible, but was also expensive. The comment in the ranks was: "If Management would only provide the equipment, we could control the quality". Management, on the other hand, was properly hesitant about investing in the equipment unless it could be clearly shown to be of value. A clear demonstration that variability in the suspected factor did not seriously affect product quality ended the controversy, and efforts were directed to more useful channels.

TABLE II—Calculations for Operating Chart for Control
Equation: D = 1.39 (163 — 1.47A — 419C)

| A | C | 1.47A | 419C | 163 — 1.47A — 419C | D |
|---|---|---|---|---|---|
| 45 | .030 | 66.2 | 12.6 | 84.2 | 117 |
| 55 | .030 | 80.8 | 12.6 | 69.6 | 97 |
| 45 | .035 | 66.2 | 14.7 | 82.1 | 114 |
| 55 | .035 | 80.8 | 14.7 | 67.5 | 94 |
| 45 | .040 | 66.2 | 16.8 | 80.0 | 111 |
| 55 | .040 | 80.8 | 16.8 | 65.4 | 91 |
| 45 | .045 | 66.2 | 18.9 | 77.9 | 108 |
| 55 | .045 | 80.8 | 18.9 | 63.3 | 88 |
| 45 | .050 | 66.2 | 21.0 | 75.8 | 105 |
| 55 | .050 | 80.8 | 21.0 | 61.2 | 85 |

$$175 = 12 + 1.47A + 419C + .72D$$

Solve this equation for either C or D; e.g., D:

$$D = 1.39\ (163 - 1.47A - 419C)$$

Now, replacing A and C by values selected in such a way as to cover their variation as indicated by the data, various values of D are calculated as shown in Table II. The resulting Operating Chart for Control is shown in Fig. 4.

A chart such as this can be used either to find the best temperature after amount of reagent has been decided; to find the best amount of reagent after temperature has been decided; or to make available many satisfactory combinations of the two. Such flexibility is desirable because of the many extraneous factors which affect such decisions.*

Example 1:

| | |
|---|---|
| Incoming Property: | 51 |
| Amount of Reagent: | .040 |
| Best Reaction Temperature: | 99 |

Example 2:

| | |
|---|---|
| Incoming Property: | 46 |
| Reaction Temperature: | 105 |
| Best Amount of Reagent: | .047 |

*Often the most important of the "extraneous" factors is cost. A simple study will usually reveal that, of several available combinations for reaching the desired quality, one does it at the least cost. Thus low cost and high quality may be made to go hand in hand.

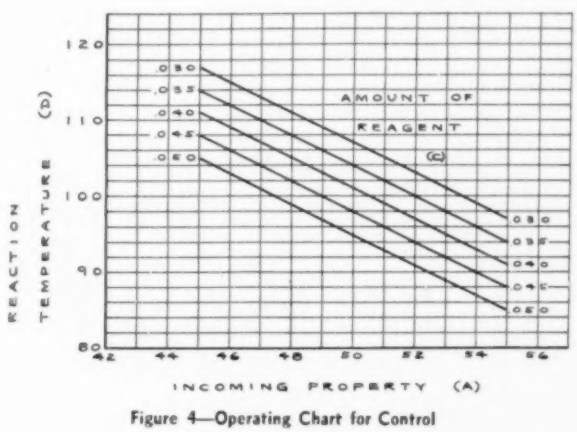


Figure 4—Operating Chart for Control

Example 3:

Incoming Property: 49

| Temperate-Reagent Combinations: | Temperature | Reagent |
|---|---|---|
| | 97 | .050 |
| | 100 | .045 |
| | 103 | .040 |
| | 106 | .035 |
| | 109 | .030 |

## CONCLUSION

Other quality control engineering projects of equal interest have been reported. The conclusion indicated is that there is an important place in the pulp and paper industry for the QC engineer.

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# Acceptance Sampling by Variables Using the Range


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**Minneapolis-Honeywell Regulator Co.**


## INTRODUCTION

Acceptance sampling involves a decision on material which has already been produced. Shall the material be accepted as submitted by the supplier (which may be a department within the company), or is the quality of the lot such that it must be sorted before acceptance? This decision may be arrived at by either of the two types of sampling, i.e. by variables or by attributes. Attribute sampling involves a go, no-go proposition. Each piece meets a specification, or it does not. Attribute sampling is easy to perform and easy to administer, but involves using fairly large samples. Variable sampling means taking the actual reading on a measurable characteristic for each piece in the sample. On the basis of these readings, the lot is passed or rejected. More information is obtained from each item inspected, and therefore a smaller sample will give the same protection as would a much larger sample under attribute sampling.

## CONDITIONS FOR USE OF ATTRIBUTE VS. VARIABLE SAMPLING

Attribute acceptance inspection is preferable when:

1. Lots are sorted before initial inspection
2. Equipment available is of a go, no-go nature
3. Personnel of the department are not sufficiently trained to go along with the rejection of a lot when no defects are found in the sample
4. The distribution form of the readings may change rapidly over a period of time (The distribution may become non-normal)

Variable sampling is useful when:

1. It takes a long time to get a single reading
2. The distribution of readings is close to normal
3. It is expensive to get a reading (destructive testing, for example)
4. A record of actual readings is helpful for future corrections in the process
5. Equipment is available to take actual readings
6. There is limited time, space or equipment to take readings

## SUBSTITUTION OF THE RANGE FOR THE STANDARD DEVIATION

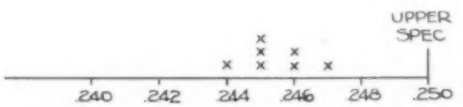
One difficulty with variable sampling is the necessary calculations. The calculation of the standard deviation makes variable sampling impractical for many industrial inspection situations. The purpose of this article is to substitute the range for the standard deviation in the plans.* Complete directions are given for drawing the acceptance chart, calculating the OC curve, obtaining AOQL plans, arriving at AQL plans, breaking up the sample into subgroups, etc. Discussion here is limited to plans that provide protection against exceeding a one-sided specification. Plans, using the range, that provide protection against exceeding two-sided specifications have been derived and used by the author, but they are not discussed in this present article.

Suppose, for example, a length of not over 0.250 is specified. The following criterion may be set up:

$$\overline{X} + k\,\overline{R}/d_2 \leq 0.250.$$

Assume the following values in a sample of seven:

(.245, .247, .244, .246, .245, .246, .245).




If one assumes that the sample is drawn from a normal population, the mean and mean range may be used as a basis for acceptance or rejection. The further the mean is below 0.250 and the smaller the mean range of the

*See Reference 11, Chapter 1, for a discussion using the standard deviation.

sample, the better is the chance that the population from which we are drawing is a good lot.

The mean range may be the range of an entire sample as above or it may be the mean of several ranges from a sample which has been divided into equal subgroups. The larger the subgroup size, the larger the mean range is likely to be. The factor $d_2$ is introduced to compensate for this. The value of $d_2$ for a subgroup size is obtained from the distribution of ranges of samples of this size drawn from a normal population. The mean of this range distribution is $d_2\sigma'$, where $\sigma'$ is the standard deviation of the normal parent population.

TABLE I — VALUES OF $k_2$ and $d_2$

| SIZE OF SUBGROUP | $d_2$ | $k_2$ |
|---|---|---|
| 2 | 1.12838 | .8525 |
| 3 | 1.69257 | .8884 |
| 4 | 2.05875 | .8798 |
| 5 | 2.32593 | .8641 |
| 6 | 2.53441 | .8480 |
| 7 | 2.70436 | .833 |
| 8 | 2.84720 | .820 |
| 9 | 2.97003 | .808 |
| 10 | 3.07751 | .797 |
| 11 | 3.17287 | .787 |
| 12 | 3.25846 | .778 |

In the above criterion, k is a certainty factor. From the criterion itself it may be seen that the larger the value of k, the greater the chance that $\overline{X} + k\ \overline{R}/d_2$ is going to be larger than 0.250. When $\overline{X} + k\ \overline{R}/d_2$ is greater than 0.250, the lot is rejected. This means that a large value of k will result in only very good lots being accepted. How to determine a value of k for a plan that will have desired protection features is covered later in this article.

It has been shown[5] that the standard deviation of the distribution of ranges of samples of a given size from a normal distribution is $k_2\sigma'$.

Table I gives numerical values of $d_2$ and $k_2$.

## PROCEDURE FOR VARIABLE SAMPLING WITH THE RANGE—ONE SIDED PROTECTION

The following criterion is set up:

$$\overline{X} + k\ \overline{R}/d_2 \leq U$$

where U is the upper specification limit. The general procedure to be followed may be stated in four steps.

1. Select a random sample of required size
2. Take and record the reading for each item of the sample
3. Obtain the mean and average range of the sample
4. Interpret the results on a chart such as that in Fig. 1

If the value of $\overline{X}$ and $\overline{R}$ obtained in a sample from a lot plots on or below the criterion line, the lot is accepted; otherwise the lot is rejected. All points on this line have the same value of k. Since the original population (the lot) was assumed to be normal, all points on the line represent the same percent defective.

## SELECTION OF THE MOST EFFICIENT SUBGROUP SIZE

The use of the range instead of the standard deviation immediately brings up the question of the most efficient subgroup size. It is perhaps best to quote a well known author[7] on the subject:

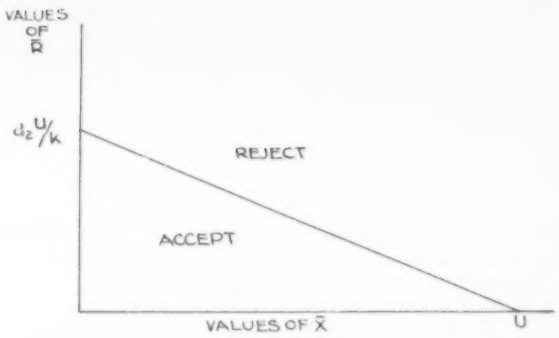



Figure 1—Acceptance Chart Using $\overline{X}$ and $\overline{R}$—Protection Against Exceeding an Upper Specification Only

"It is known that the distribution of the range in normal samples depends on the sample size n, is independent of the population mean, but dependent on its standard deviation $\sigma'$. Moreover, for large n (say $n > 20$), even small departures from normality in the tails of the parental distribution have a considerable effect on the distribution of the range. Furthermore, the relative efficiency of the range as an estimator of $\sigma'$ decreases as n increases. Hence, in practice when n exceeds say 12, it is preferable to divide the sample into a number of groups and take a weighted mean of the several group ranges. The question of the subdivision which will give the smallest variance of the estimate has been considered by Pearson (1932)[9] and by Grubbs and Weaver (1947)[6]. It is found that groups of seven or eight are the best. It will generally be advantageous to have equal groups of about this size and use the average of the group ranges."

TABLE II — $\sigma(\overline{R}/d_2)$ for Subdivided Sample

| Breakup of Sample | $\sigma(\overline{R}/d_2)$ |
|---|---|
| One subgroup of twelve | $.2388\sigma'$ |
| Two subgroups of six | $.2366\sigma'$ |
| Three subgroups of four | $.2467\sigma'$ |
| Four subgroups of three | $.2624\sigma'$ |
| Six subgroups of two | $.3084\sigma'$ |

The best subgroup size to use with a given sample size may be arrived at by calculating the standard deviation of $\overline{R}/d_2$, which we denote by $\sigma\ (\overline{R}/d_2)$:

$$\sigma\ (\overline{R}/d_2) = \frac{k_2\sigma'}{d_2\sqrt{m}}$$

where $\overline{R}$ is the mean subgroup range, m is the number of subgroups, $d_2$ and $k_2$ are the values (Table I) for the subgroup size in question. The subgrouping which gives the smallest value of $\sigma\ (\overline{R}/d_2)$ is superior.

For example, a sample of twelve may be broken into subgroups in five ways. To judge which is the best breakup, $\sigma\ (\overline{R}/d_2)$ is calculated for each. For two subgroups of six, $\sigma\ (\overline{R}/d_2) = 0.8480\ \sigma'/2.53441\sqrt{2} = 0.2366\ \sigma'$. Table II shows that two subgroups of six is the breakup of a sample of 12 which gives an estimate of the range with the smallest error.

## THE USE OF SUMS RATHER THAN MEANS

In the actual application of variable plans in the factory, it is much better to use sums rather than means. This saves the line inspectors two division operations and also makes for more accurate results. The criterion $\overline{X} + k\ \overline{R}/d_2 \leq U$ is changed in the following manner:

$$(\Sigma X)/n + k\ (\Sigma R)/(md_2) \leq U$$
$$\Sigma X + nk\ (\Sigma R)/(md_2) \leq nU$$
$$\Sigma X + k'\ \Sigma R \leq nU$$

where

n = sample size
m = number of subgroups
$k' = nk/md_2$.

The acceptance chart then becomes that shown in Fig. 2. The inspector simply takes the sum of the readings and the sum of the subgroup ranges and interprets them as per the chart.

*Example 1*

$k = 1.00$ $\quad d_2 = 2.70436$

$n = 21$ $\quad k_2 = 0.833$

$m = 3$ (subgr. size = 7) $\quad U = 10$ grams

$$\Sigma X + [21(1.00)/3(2.70436)]\ \Sigma R \leq (21)(10)$$
$$\Sigma X + [21(1.00)/8.11308]\ \Sigma R \leq 210$$
$$\Sigma X + 2.5884\ \Sigma R \leq 210$$

| $\Sigma X$ | $\Sigma R$ |
|---|---|
| 210 | 0 |
| 207.4 | 1 |
| 197.1 | 5 |

Figure 3 then provides graphical criteria for acceptance-rejection decisions.

The two scale transformations result in the mean being multiplied by the sample size and the mean range being multiplied by the number of subgroups. We thus plot $\Sigma X$ vs. $\Sigma R$ instead of $\overline{X}$ vs. $\overline{R}$.

The formula for a lower specification would be

$$\Sigma X - (nk/md_2)\ \Sigma R \geq nM$$
$$\text{or } \Sigma X - k''\ \Sigma R \geq nM$$

where M is the lower specification and $k'' = nk/md_2$.

Using the data of the previous example but with M = 5 grams we have

$$\Sigma X - 2.5884\ \Sigma R \geq 105$$

and the corresponding acceptance chart then becomes that shown in Fig. 4.

## MEANING OF $K_p$

Assume a normal population with mean $\mu$ and standard deviation $\sigma$. The picture of such a distribution is at the left in Fig. 5. The curve on the right is the same population transformed so that the abscissa values are normal deviates. The symbol $K_p$ is used for the normal deviate exceeded by a percent equal to p. The value of $K_p$ may be positive or negative, with $K_p$ equal to zero when p is 50 percent. There are two tables necessary in using variable acceptance sampling. They are:

(1) A table giving the normal deviate exceeded by a given percent (Table 1.1 pp. 18 of Reference 11.)

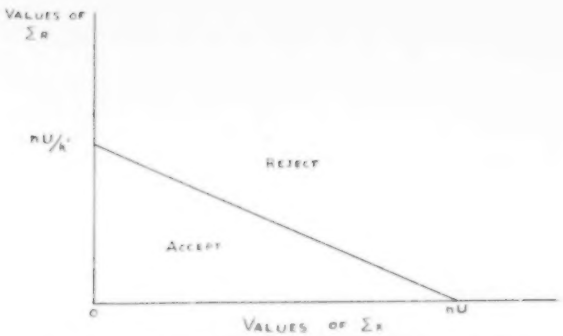



Figure 2—Acceptance Chart Using $\Sigma X$ and $\Sigma R$—Protection Against Exceeding an Upper Specification Only

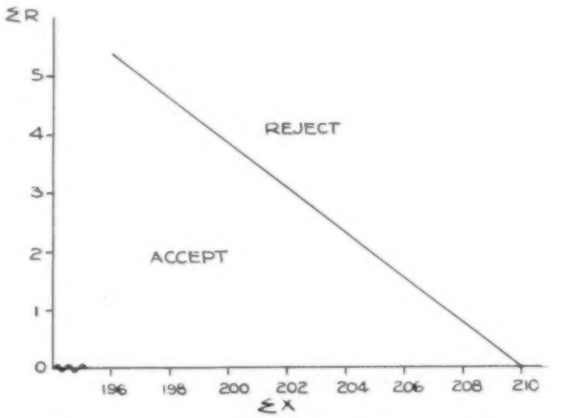



Figure 3—Acceptance Chart for an Upper Specification Plan

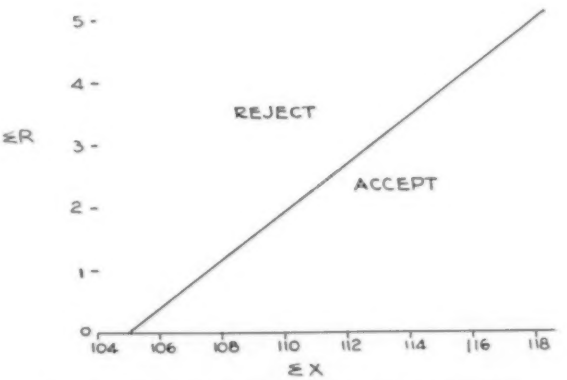



Figure 4—Acceptance Chart for a Lower Specification Plan

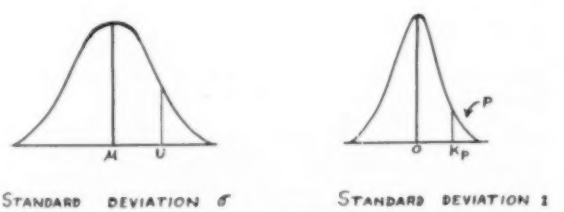



Figure 5—Normal Curves in Natural Units and in Standard Units

(2) A table giving the percent corresponding to a given normal deviate (Table 1.5 pp. 31 of Reference 11.)

There is a single value of $K_p$ for any given percent p. For example, if p is five percent, then $K_p$ is 1.64485. If p is greater than 50 percent, $K_p$ is negative. Also, if $K_p$ is 2.43, for example, then p is 0.75 percent. If $P_A$ is the probability of acceptance of a lot, then there is a $K_{PA}$ to correspond to it. Thus, for $P_A = 90\%$, $K_{90\%} = -K_{10\%} = -1.28155$. (Table 1.1, Ref. 11)

## METHOD FOR OBTAINING A PLAN WITH GIVEN AQL AND PRODUCER'S RISK

Figure 6 is a graph of AQL as a function of n and k. Each curve is for a specified n. The producer's risk is five percent throughout the graph. It is usually best to decide on an AQL and a sample size and then obtain k from the graph. If one desires an AQL of two percent and there is enough time to take a sample of 21, then the graph shows that a k of 1.49 should be used. It is also possible to interpolate for sample sizes not given. Another example would be an AQL of one percent, a sample of 49, and k equal to 1.90. The breakup of the sample sizes on this graph is as follows:

7 subgroups of 7 = 49
5 subgroups of 7 = 35
4 subgroups of 7 = 28
3 subgroups of 7 = 21
2 subgroups of 8 = 16
2 subgroups of 6 = 12
1 subgroup of 8 = 8
1 subgroup of 5 = 5
1 subgroup of 3 = 3

## FORMULA FOR k WHEN n AND ONE POINT ON THE OC CURVE ARE SPECIFIED

Let $P_A$ = probability of acceptance of a lot p% defective

$K_{PA}$ = normal deviate exceeded by a probability $P_A$

(Use Table 1.1, Ref. 11, for this.)

p = peprcent defective associated with $P_A$

$K_p$ = corresponding normal deviate (Use Table 1.1, Ref. 11, for this.)

Then in the Appendix to this article, it is shown that

$$k = (K_p \pm \sqrt{K_p^2 - ab})/a$$

$$a = 1 - k_2^2 K_{PA}^2/md_2^2$$

$$b = K_p^2 - K_{PA}^2/n.$$

The plus sign is used if $P_A < 0.5$ and the minus sign if $P_A > 0.5$.

If p is taken as the AQL value, then one minus the $P_A$ associated with the AQL value is the producer's risk. The values of AQL, $P_A$, and n may be substituted in the above equation to obtain a specific AQL plan for the given producer's risk.

*Example 2*

Given p = AQL = 3%; $K_p = 1.88079$;
producer's risk = $1 - P_A = 1 - 90\% = 10\%$;
$K_{PA} = -1.28155$; n = 21 (3 subgroups of 7).

Then: $a = 1 - [(.833)^2 (-1.28155)^2]/[3\ (2.70436)^2]$
$= 1 - [(.693889)\ (1.642370)]/[3\ (7.313563)]$
$= .948059$;

$b = (1.88079)^2 - 1.642370/21$
$= 3.537371 - 1.642370/21$
$= 3.459163$;

$ab = 3.279491$;

$$k = \frac{(1.88079 - \sqrt{3.537371 - 3.279491}}{0.948059}.$$
$= 1.45.$

Therefore a sample of 21 items and a k of 1.45 will give a plan with an AQL of three percent and a producer's risk of ten percent. The above formula for k may be used to obtain a plan with any point specified on the OC curve, provided the sample size n is also specified.

## CALCULATION OF THE OC CURVE FOR A GIVEN PLAN

In the Appendix to this article it is shown that the equation used to obtain values on the OC curve is

$$K_{PA} = \frac{k - K_p}{\sqrt{1/n + k^2 k_2^2/md_2^2}}$$

*Example 3*

Given n= 12 (2 subgr. of 6) $k_2 = 0.8480$
p = 10% $d_2 = 2.53441$
k = 1.00 m = 2

Then: $$K_{PA} = \frac{1.00 - 1.28155}{\sqrt{1/12 + (0.8480)^2 / 2(2.53441)^2}}$$
$= -0.28155/\sqrt{0.13931012} = -0.28155/0.3732430$
$= -0.754$

Table 1.5 Ref. 11 gives $P_A = 0.2254$, but here we have $P_A = 1 - 0.2254$ because the table value must be subtracted from one when $K_{PA}$ is negative. The table value is taken directly if $K_{PA}$ is positive. Thus a lot that is ten percent defective has a 77.5 percent chance of acceptance.

It is also possible to take a value of $P_A$ and find the value of p which would be accepted this often:

$$K_p = k - K_{PA}\sqrt{1/n + k^2 k_2^2/md_2^2}.$$

*Example 4*

Given: $P_A = 36.39\%$ ($K_{36.39\%} = 0.34809$ from Table 1.1, Ref. 11)

k = 1.50

n = 12 (2 subgroups of 6).

Then: $$K_p = 1.50 - 0.34809\sqrt{\frac{1}{12} + \frac{2.25(0.8480)^2}{2(2.53441)^2}}$$
$= 1.50 - (0.34809)\ (0.45747)$

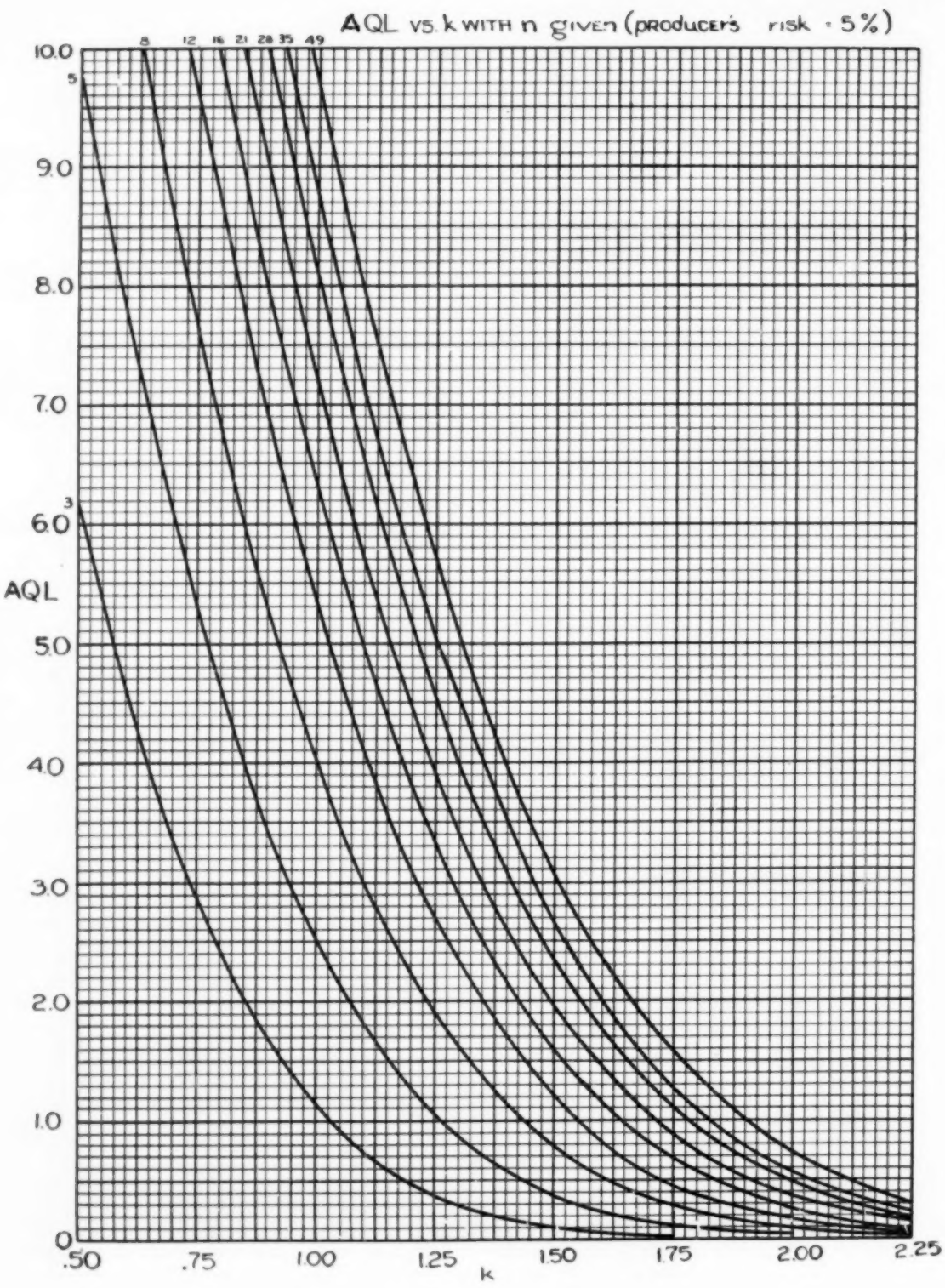



Figure 6—Graph of AQL Values

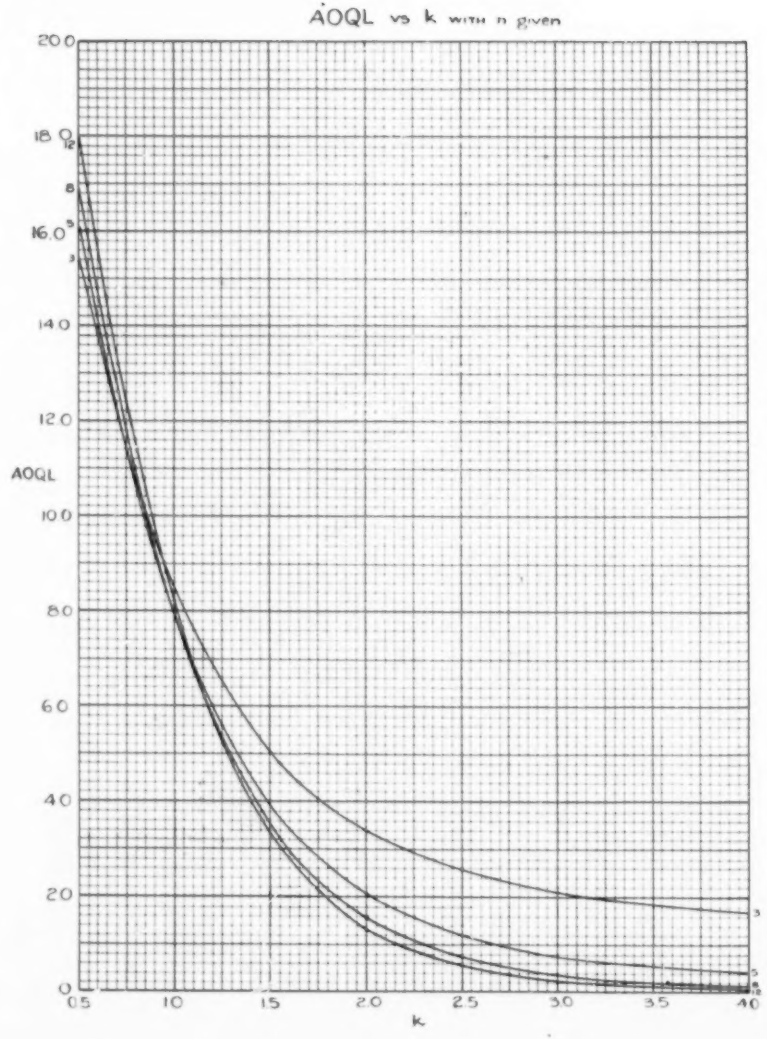



Figure 7a—Graph of AOQL Values

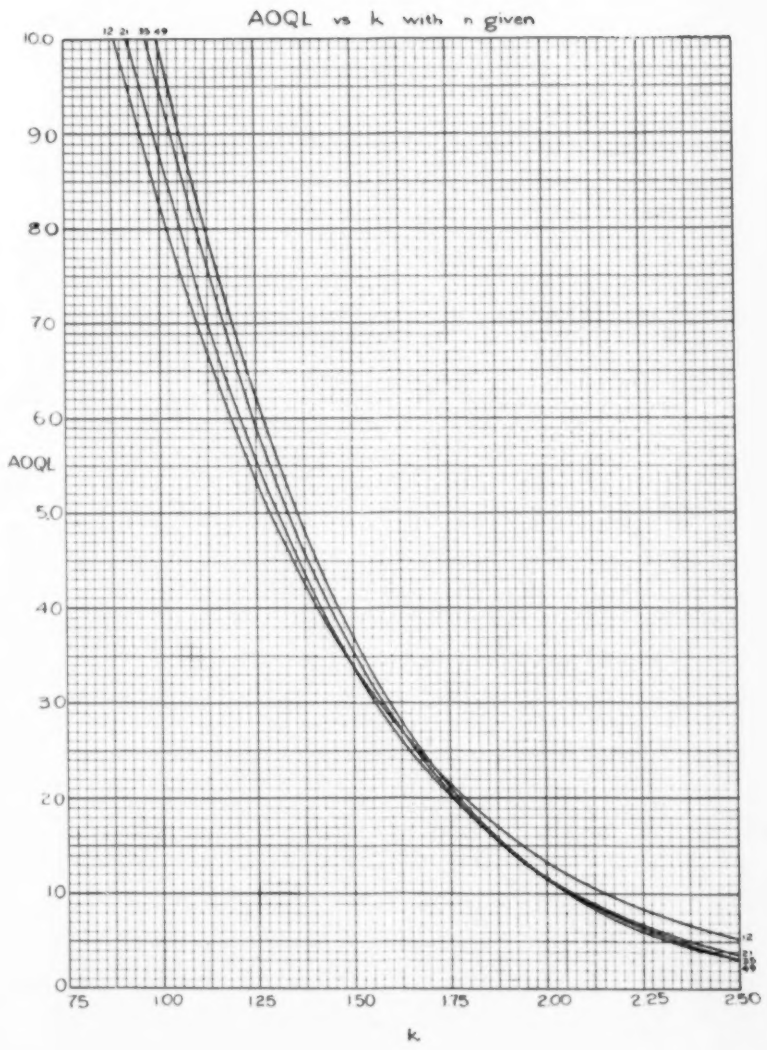



Figure 7b—Graph of AOQL Values

$= 1.50 - 0.15924$

$= 1.341.$

The value of p is then obtained from Table 1.5, Ref. 11. For $K_p = 1.341$, we find p = 9.00 percent.

In the above sampling plan (n = 12, 2 subgroups of 6, and k = 1.50) a nine percent lot has a 36.39 percent chance of acceptance. The value of p for a 63.61 percent chance of acceptance is easily obtained:

$K_p = 1.50 + 0.15924$

$= 1.65924$

from which

p = 4.86% (again using Table 1.5, Ref. 11.)

Therefore a 4.86 percent defective lot has a 63.61 percent chance of acceptance. These are two points on the OC curve. Other points on the curve may be found using a similar procedure. Table III gives points on the OC curve for the plan n = 12, 2 subgroups of 6, and k = 1.50.

TABLE III — OC Values for n=2, 2 subgroups of 6
k=1.50

| p | $P_A$ |
|---|---|
| 1.2 | 95.0 |
| 1.9 | 90.0 |
| 3.5 | 75.0 |
| 4.9 | 63.6 |
| 6.7 | 50.0 |
| 9.0 | 36.4 |
| 11.7 | 25.0 |
| 18.0 | 10.0 |

### k vs. AOQL

The AOQL is the maximum value of the average outgoing quality (AOQ). An excellent workable definition of AOQ is given by Greb and Berrettoni.[9] It is equivalent to

$$AOQ = pP_A$$

where p is the percent defective in the lot and $P_A$ is the probability that a p-percent defective lot will be accepted.

The charts in Figs. 7a and b give the k value for the expressions $\overline{X} + k\,\overline{R}/d_2 \leq U$ or $X - k\,\overline{R}/d_2 \geq M$ which will give the desired AOQL. Each sample size has a specific curve. For example, with a sample size of three, (Fig. 7a) a k value of 1.50 will give an AOQL of five percent. The curves given are for the best breakup of the sample size specified. The breakup of the sample on the two charts is as follows:

7 subgroups of 7 = 49

5 subgroups of 7 = 35

3 subgroups of 7 = 21

2 subgroups of 6 = 12

1 subgroup of 8 = 8

1 subgroup of 5 = 5

1 subgroup of 3 = 3.

### GLOSSARY OF TERMS

AOQ —Average outgoing quality

AOQL —Average outgoing quality limit

$d_2$ —The mean of the range distribution in sigma units for the subgroup size used

k —A constant multiple which is a parameter of the plan selected

$k_2$ —The standard deviation of the range distribution in sigma units for the subgroup size used

$K_p$ —The normal deviate exceeded by p percent

$K_{P_A}$ —The normal deviate exceeded by $P_A$ percent

$\mu$ —Mean of the population from which the samples are being drawn

M —A lower specification limit

m —The number of subgroups

n —The sample size

N —The lot size

p —Percent defective in a lot or population

$P_A$ —Probability of acceptance of a lot under a sampling plan

$\overline{R}$ —Mean range of the sample

$\overline{R}'$ —True mean value of $\overline{R}$ for the subgroup size used ($\overline{R}'/d_2 = \sigma'$)

$\sigma'$ —Standard deviation of the population from which samples are being drawn

$\Sigma R$ —The sum of subgroup ranges in a sample

$\Sigma X$ —The sum of the readings in a sample

U —An upper specification limit

$\overline{X}$ —The mean of a sample

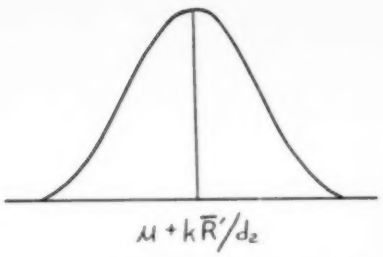
### Appendix

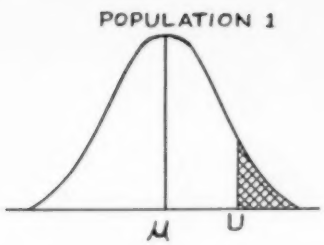
*Distribution of $\overline{X} + k\overline{R}/d_2$*

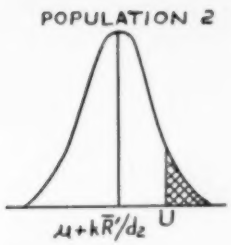
The theoretical frequency distribution of $\overline{X} + k\overline{R}/d_2$ is illustrated graphically in Fig. 8. The population being sampled is assumed to be normal.

The distribution is very close to normal. $\overline{X} + k\overline{R}/d_2$ is a linear combination of independent variables. One variable is normally distributed and the other is fairly close to normal[10,] at least for subgroups 310. The mean of the distribution is $\mu + k\overline{R}'/d_2$, where $\mu$ is used to represent the mean of the original population and $\overline{R}'$ for the true mean value of $\overline{R}$ for the subgroup size used. Also, $d_2\sigma'$ would be the mean of the range distribution for the subgroup size used. The population value of $\sigma'$ is exactly equal to $\overline{R}'/d_2$.

The standard deviation of the population of $\overline{X} + k\overline{R}/_2$ is $\sigma' \sqrt{1/n + k_2^2/md_2^2}$. Let n be the sample size, $k_2\sigma'$ the




(Left) Figure 8—Population of $\bar{X} + kR'/d_2$ in Samples from a Normal Population. (Right) Figure 9—Populations Involved in Variable Sampling Using the Range.

standard deviation for the range distribution for the subgroup size used, and m the number of subgroups. Pearson[10] shows that the standard deviation of $\bar{X} + k\bar{R}/d_2$ is $\sqrt{\sigma_{\bar{x}}^2 + k^2\sigma_R^2/d_2^2}$ This expression reduces $\sqrt{\sigma'^2/n + k^2k_2^2\sigma'^2/md_2^2}$ and finally to the original expression given above. The populations in Fig. 9 are set up with U representing an upper specification limit.

In Fig. 9 Population 1 is the parent population of individual X values in the lot. The cross-hatched area represents the percent defective in the lot.

Population 2 is the distribution of $\bar{X} + k\bar{R}/d_2$ in samples drawn from Population 1. The cross-hatched area represents samples rejected by the criterion $\bar{X} + k\bar{R}/d_2 \leq U$. Let $P_A$ = the probability of acceptance. Then the area to the right of U (probability of rejection) will be $1 - P_A$. It should be noted that $K_{1-P_A} = -K_{P_A}$. The normal deviate may be used to separate the distribution into acceptance and rejection regions. Therefore:

$$\frac{U - (\mu + k\bar{R}'/d_2)}{\sigma'\sqrt{1/n + k^2k_2^2/md_2^2}} = -K_{P_A}$$

or

$$(U - \mu)/\sigma' - kR'/\sigma'd_2 = -K_{P_A}\sqrt{1/n + k^2k_2^2/md_2^2}$$

But $\bar{R}'/d_2 = \sigma'$ and $K_p = (U - \mu)/\sigma'$. This is in normal deviate form, where p is the percent defective in Population 1. Hence:

$$K_p - k = -K_{P_A}\sqrt{1/n + k^2k_2^2/md_2^2}$$

$$k - K_p = K_{P_A}\sqrt{1/n + k^2k_2^2/md_2^2}$$

$$k^2 - 2kK_p + K_p^2 = K_{P_A}^2(1/n + k^2k_2^2/md_2^2)$$

$$(1 - k_2^2K_{P_A}^2/md_2^2)k^2 - 2K_pk + (K_p^2 - K_{P_A}^2/n) = 0.$$

Solving the quadratic:

$$k = (2K_p \pm 2\sqrt{K_p^2 - ab})/2a$$

$$= (K_p \pm \sqrt{K_p^2 - ab})/a$$

where

$$a = 1 - k_2^2K_{P_A}^2/md_2^2$$

$$b = K_p^2 - K_{P_A}^2/n.$$

*Derivation of OC Curve*

It was shown in the preceding development that

$$k - K_p = K_{P_A}\sqrt{1/n + k^2k_2^2/md_2^2}$$

Therefore

$$K_{P_A} = \frac{k - K_p}{\sqrt{1/n + k^2k_2^2/md_2^2}}$$

The equation can easily be rearranged to solve for $K_p$ instead of $K_{P_A}$.

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# Quality Incentive

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We have had, for some time, quantity incentive plans in manufacturing plants, in business office routines, and in other places as well.

In some of these applications, at least, it is felt that quality is sacrificed to the economic pressure for quantity. Many operators feel, perhaps not without reason, that their overall return is maximized by increasing their rate of production even though this results in their having to repair or to replace the augmented number of defectives "on their own time." "On their own time" means that they can not produce additional units while they repair or replace the previously produced defective ones.

The tendency to produce quantity at the expense of quality is enhanced if the unit of the operator's work is accepted or rejected on the basis of a sampling scheme.

To combat this inclination on the part of the operator it is felt, in some applications at least, that a quality incentive would be helpful. A general formula would be most useful if one could be written, but a specific example and the bases for its details may be of interest and help.

## BACKGROUND OF THE PLAN

In the embossing operation of the Esquire-Coronet Supscription Fulfillment process, the subscriber's name, the subscriber's address, and a subscription code are impressed on a Speedaumat plate for servicing of the subscriber's order.

An error rate of one per cent has been set as the standard for this operation. This is interpreted to mean that an operator suited to this type of work should, after proper training and a reasonable time for experience, attain and maintain an overall error rate of not more than one defectively embossed plate out of 100 produced.

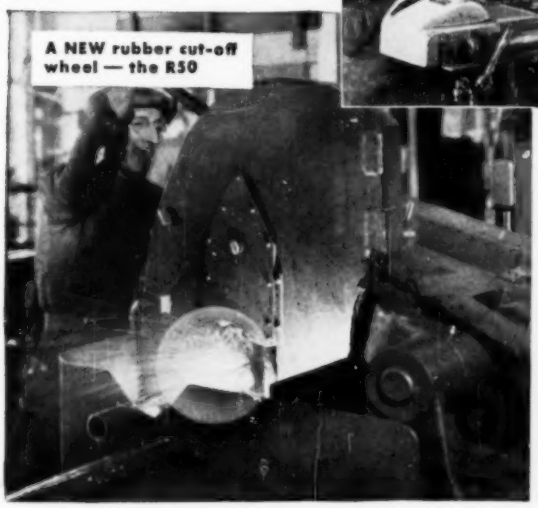
The unit of the operator's work is accepted or detailed on the basis of the Dodge-Romig SA-1.0 table. This guarantees, if the proof-reading is properly done, that the long run proportion of defective plates in the files will not be greater than one per cent, regardless of the individual operator's error rate.

The bases for quality incentive come, in this application, from two considerations. Because of the present labor situation, the company feels that it must be content with an embossing error rate greater than the standard set — a value of, say, two per cent. If the operator's rate of error production is less than this reference value, the cost of proofreading is thereby reduced. This reduction is a result of the lessening of the frequency of detailing which accompanies a lowered error rate. The decrease in detailing lowers the ratio of the average number of plates inspected to the total number produced. This ratio approaches a limiting value (which depends upon the

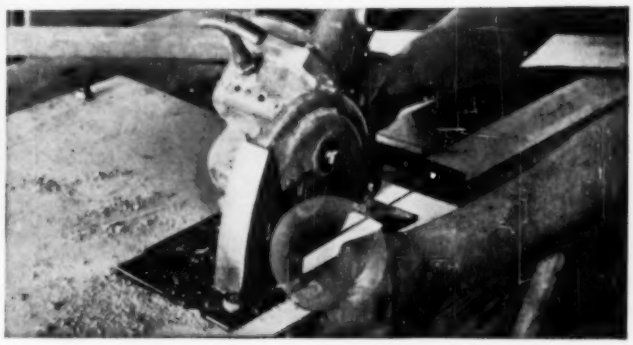
TABLE I—Computation of I/N and AOQ for Representative Values of p
AOQL = 1%; N = 150; n = 32; C = 0

| p(%) | np | $P_a$ | I | I/N | AOQ(%) |
|---|---|---|---|---|---|
| 0.0 | | 1.000 | 32.00 | 0.2133 | 0 |
| 0.1 | 0.032 | 0.969 | 35.66 | 0.2377 | 0.0762 |
| 0.2 | 0.064 | 0.938 | 39.32 | 0.2621 | 0.1476 |
| 0.3 | 0.096 | 0.909 (0.908) | 42.74 | 0.2849 | 0.2145 |
| 0.4 | 0.128 | 0.881 (0.87) | 46.04 | 0.3069 | 0.2772 |
| 0.5 | 0.160 | 0.853 (0.85) | 49.35 | 0.3290 | 0.3355 |
| 0.6 | 0.192 | 0.826 (0.83) | 52.53 | 0.3502 | 0.3899 |
| 0.7 | 0.224 | 0.800 (0.80) | 55.60 | 0.3707 | 0.4406 |
| 0.8 | 0.256 | 0.775 (0.77) | 58.55 | 0.3903 | 0.4878 |
| 0.9 | 0.288 | 0.750 (0.75) | 61.50 | 0.4100 | 0.5310 |
| 1.0 | 0.320 | 0.727 (0.73) | 64.21 | 0.4281 | 0.5719 |
| 1.1 | 0.352 | 0.704 (0.70) | 66.93 | 0.4462 | 0.6092 |
| 1.2 | 0.384 | 0.681 (0.68) | 69.64 | 0.4643 | 0.6430 |
| 1.3 | 0.416 | 0.660 (0.66) | 72.12 | 0.4808 | 0.6750 |
| 1.4 | 0.448 | 0.640 (0.64) | 74.48 | 0.4965 | 0.7049 |
| 1.5 | 0.480 | 0.620 (0.62) | 76.84 | 0.5123 | 0.7317 |
| 1.6 | 0.512 | 0.600 (0.60) | 79.20 | 0.5280 | 0.7552 |
| 1.7 | 0.544 | 0.581 (0.58) | 81.44 | 0.5429 | 0.7771 |
| 1.8 | 0.576 | 0.563 (0.56) | 83.57 | 0.5571 | 0.7972 |
| 1.9 | 0.608 | 0.545 (0.54) | 85.69 | 0.5713 | 0.8147 |
| 2.0 | 0.640 | 0.528 (0.53) | 87.70 | 0.5846 | 0.8308 |
| 2.5 | 0.800 | 0.449 (0.44) | 97.02 | 0.6468 | 0.8833 |
| 3.0 | 0.960 | 0.383 (0.38) | 104.81 | 0.6987 | 0.9039 |
| 3.5 | 1.120 | 0.327 (0.33) | 111.41 | 0.7428 | 0.9006 |
| 4.0 | 1.280 | 0.279 (0.27) | 117.08 | 0.7805 | 0.8780 |
| 4.5 | 1.440 | 0.238 (0.24) | 121.92 | 0.8128 | 0.8429 |
| 5.0 | 1.600 | 0.202 (0.20) | 126.16 | 0.8411 | 0.7945 |

**For high production** — The new Norton B9 resinoid bonded cut-off wheel cuts free and cool at speeds up to 16,000 surface feet per minute. An exceptional performer on both ferrous and non-ferrous metals. ▶




**Where clearance counts** — The new Norton R50 rubber bonded cut-off wheel, has the unusual advantage of built-in chip clearance. Ideal for wet-cutting of ferrous or non-ferrous bar stock, in diameters up to 6". ◀



**Stronger, safer, more versatile** — The popular Norton BN cut-off wheel, resinoid bonded, is used on all types of machines for the widest variety of metallic and non-metallic applications. ▶

# Cost-cutters for cutting-off!

## Norton wheels bring the

# "TOUCH of GOLD"

## to every job

Each type of cut-off wheel in the broad Norton line has individual features for top efficiency and economy in its particular job range. For example:

**The new Norton B9** resinoid bonded cut-off wheel is made with either smooth sides or the rougher "F" sides for more clearance. A high production wheel, the B9 cuts free and cool, with a minimum of burning and will give you long, money-saving service in the widest range of metal-cutting applications.

**The new Norton R50** cut-off wheel, rubber bonded, is designed especially for wet-cutting of bar stock up to 6" diameter. Built-in chip clearance is an advantage that helps assure freer, faster cutting with maximum service life.

**Long a great favorite** for metallic and non-metallic cut-off jobs, the resinoid bonded BN wheel features versatility and safety. On all types of machines — on jobs ranging from cutting tile to track slotting — the BN delivers up to six times longer wheel life, with breakage practically eliminated.

**Other outstanding** Norton cut-off wheels: the resinoid bonded B2, a valuable tool room wheel and also widely used on non-metallic materials; the rubber bonded R30 for small diameter work and fine slotting; and the highly durable, rubber bonded R20 that resists severest dressing action.

**Quality Control** is an important factor in the production of all Norton cut-off wheels—from the moment that the abrasives, bonds and other raw materials enter the mile-long Norton plant until the finished cut-off wheels are shipped. NORTON COMPANY, Worcester 6, Mass. Distributors in all principal cities.

W-1517A

NORTON

ABRASIVES

*Making better products... to make other products better*

lot size) as the error rate goes to zero.

The other basis for such a quality incentive has to do with complaints. The subscriber may occasionally have reason to complain about non-delivery of magazines, incorrect termination of his subscription, failure to send a card to the recipient of his gift, *et cetera*. Some of these "squawks" arise from errors in embossing which get through the proof-reading operation as a result of an AOQL acceptance plan (and perhaps, too, due to errors in proof-reading). But fewer errors will be passed on to the subscriber if the operator does his work more accurately, and the subsequent lowering in number of complaints not only represents a saving to the company in adjusting effort, but also in subscriber good will.

We use this set of symbols:

p = operator's error rate in percent defective (determined on the basis of SA-1.0 samples only)

$\bar{p}$ = expected error rate (2%) an arbitrary figure based upon observation of what is happening, or upon that operator error performance which will be regarded as satisfactory

n = sample size (determined from SA-1.0 table)

N = lot size (usually 150 plates in this application)

$P_a$ = probability of accepting by a sampling plan, a lot of size N which is p-percent defective.

I = average number of plates inspected per lot of size N and of quality p

AOQ = average outgoing quality (going out from the inspection operation, provided correct proof-reading was done) in percent defective

AOQL = average outgoing quality limit

c = acceptance number

i = average cost in cents of proof-reading each plate

a = average cost in dollars of adjusting each complaint

L = number of lots produced in a given time (say, one week)

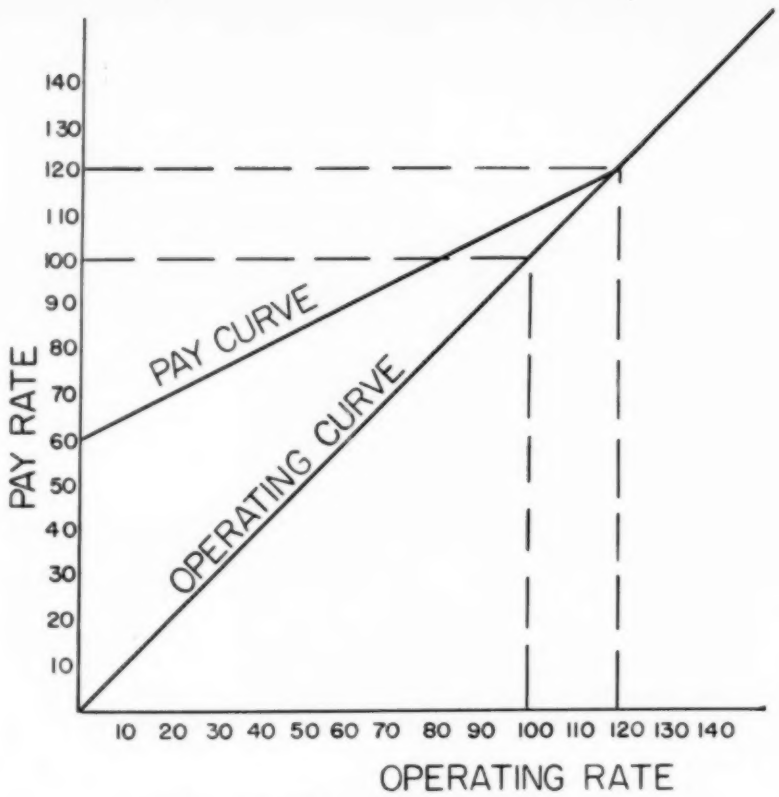



Figure 1—Pay-Operating Graph for Quantity Incentive Plans

r = ratio of complaints to errors existing on plates in files

Preliminary computations are illustrated in Table I. This table shows the I values and the AOQ values corresponding to representative values of p in connection with a sampling acceptance/rectification plan—Dodge and Romig's SA-1.0 plan, 1% AOQL, with N=150, n=32, c=0. $P_a$ values were read from Table G, in E. L. Grant's *Statistical Quality Control* (McGraw - Hill). This assumes that the Poisson Exponential Binominal Limit is a sufficiently good approximation to these probabilities. Rounding off was done upward, even for values somewhat below the usual separation line, as a proof reader is more likely to "miss" a defective than to call a good plate bad.

It is interesting to note how close to these $P_a$ values one comes by use of a chart such as the one in Dodge and Romig's book (opposite page 44) for the cumulative probability values—Poisson Exponential. The values given under the $P_a$ column in the parentheses, are those obtained from this curve with just the eye as a guide, no ruler or other scaling device used. The curve-obtained quantities were written down a day or two before Table G values were read off. However, those read from the chart give no more than two-digit accuracy in $P_a$ and in I.

I is computed from the relation:

$$I = nP_a + (1 - P_a)\,N \qquad (1)$$

and AOQ from the formula:

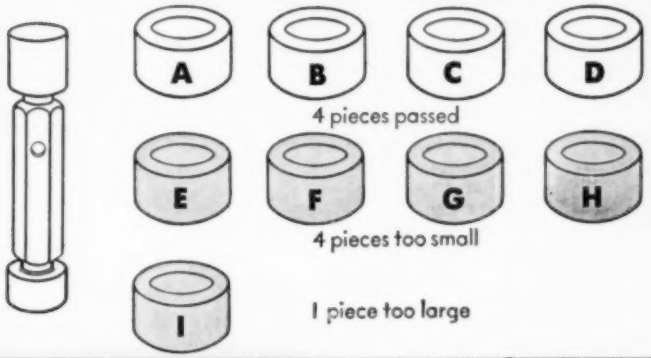
$$AOQ = p\,(1 - I/N) \qquad (2)$$

the defectives being replaced by good plates. I/N is included not only because it makes the following formulas somewhat more symmetrical, but principally because the I/N value does not change much as N varies within wide limits (from N = 150 to N = 250, I/N goes from 0.58 to 0.54 for p = 2.0%).

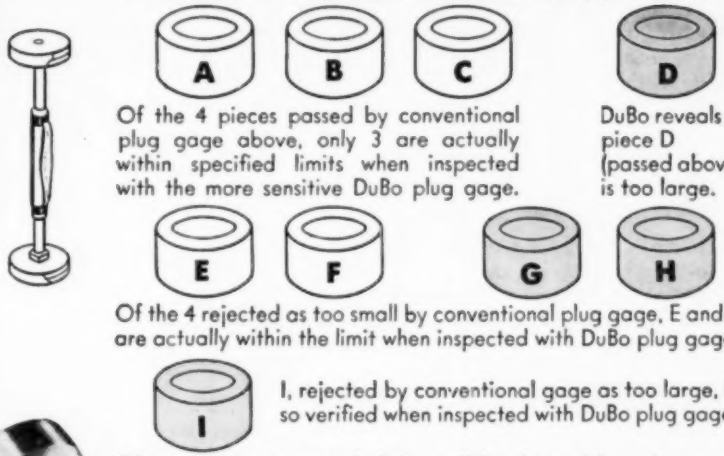
Although four digits have been retained for the recorded values for I/N and for AOQ, it should be

# An ABC Demonstration of DuBo* Plug Gage Superiority

**Inspection of 9 pieces using conventional plug gage**
**Bore Diam. 1.500"; Total Tolerance .001"**




**RESULTS of same inspection using DuBo Plug Gage**




Of the 4 pieces passed by conventional plug gage above, only 3 are actually within specified limits when inspected with the more sensitive DuBo plug gage.

DuBo reveals piece D (passed above) is too large.

Of the 4 rejected as too small by conventional plug gage, E and F are actually within the limit when inspected with DuBo plug gage.

I, rejected by conventional gage as too large, is so verified when inspected with DuBo plug gage.

**Of nine pieces inspected, DuBo reclaimed two false rejects and rejected one piece that had been passed by ordinary plug gage inspection. Apply even a fraction of this ratio to a day's production in your own plant and you'll realize the advantage of using DuBo plug gages.**

*U.S. and Foreign Patents Granted

At left:
SINGLE END
DuBo Plug. Sizes
1.510" to 6.010"

At right:
DOUBLE END
DuBo Plug. Sizes
.240" to 1.510"

## DuBo Plugs Wear 5 to 10 Times Longer than Conventional Plugs

The spherical gaging surface of the DuBo plug gage, specially relieved, has the advantage of easy entry, with contact only at the point of gaging. Lightness in weight, sensitivity and finger-tip control also mean speed and less wear.

## Don't Let Profits "Fly Out the Window"

You'll actually save money by using this modern plug gage instead of the out-moded cylindrical plug. DuBo keeps down that high cost of parts needlessly rejected or incorrectly passed. It's all in the design. DuBo plugs simply check better because of the spherical principle on which they are based.

## DuBo Saves Inspection Man-Hours

DuBo is only about one-fifth the weight of corresponding conventional plug gages. This factor, coupled with "go" and "not go" color identification, definite check, ease of entry and absence of jamming, reduces inspection time, saves money and increases profitable production! **Write or phone any questions you have on this vastly better checking device.**

**STANDARD GAGE CO., Inc., Poughkeepsie, N.Y.**

borne in mind that their accuracy is limited by the interpolation for $P_a$, and subsequent operations. I is accurate to within ± 0.001. AOQ values have varying absolute accuracies, from ± 0.0006 at p = 0.7%, to ± 0.0016 at p = 2.0%, to ± 0.0032 at p = 4.0%. These values are based on the assumption that the p-values are known exactly and that the interpolation for $P_a$ is subject to an error of as much as ± 0.001—±0.0005 from rounding off at time of construction of the table, and ± 0.0005 from rounding off at interpolation.

We write down, now, the two formulas for savings realized by the company due to improvement of quality performance with respect to $\bar{p}$. Both of these expressions are for a standard length of time, say, one week.

Saving (cents) due to decreased ($p<\bar{p}$) inspection
$$= [(I/N)_{\bar{p}} - (I/N)_{p}]\text{Nil} \qquad (3)$$

Saving (cents) due to fewer ($p<\bar{p}$) complaints
$$= [(AOQ)_{\bar{p}} - (AOQ)_{p}]\text{NaLr} \qquad (4)$$

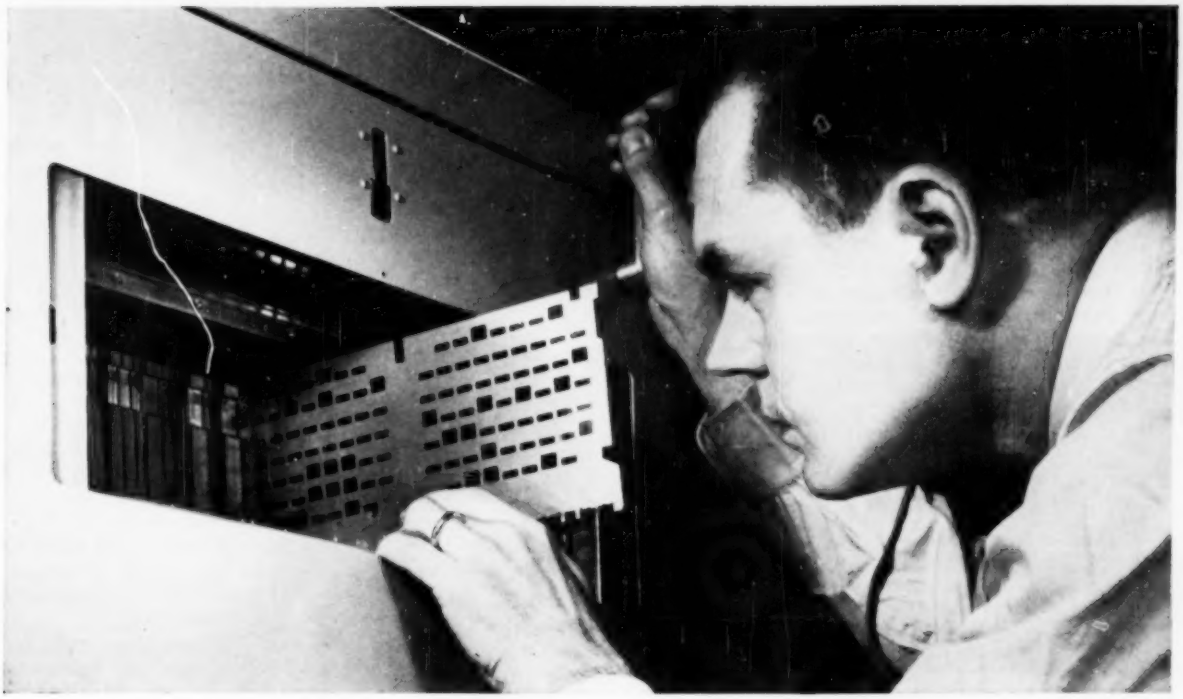
Out of all of this, the following plan seemed to have some merit and has been proposed to the Subscription Fulfillment Division of Esquire-Coronet. It is only fair to acknowledge that many of the details of this plan are a result of conferences with the subscription manager, Mr. J. L. Ross, and the industrial engineer, Mr. P. C. Miller, at Esquire-Coronet.

## THE PROPOSED PLAN

Assuming that a certain portion (say 50 percent—some people don't know, for example, when their subscription should end and thus they renew upon notice from the publisher) of such errors as we count lead to complaints, we propose that a percentage of the savings realized by the company be turned over to the employee-embosser. For the purposes of this paper, let us say, 60 percent. Some of the difference could well be used to upgrade the proof-reader, as his (her) work is of paramount importance to any plan based on a sampling scheme. The pay which an embosser receives would then be her base pay, a quantity bonus, and a quality bonus. She might receive a quality increment even though her quantity production is somewhat below norm

**TABLE II—Dollar Increments to Base Wage of $40.00 per Week Due to Quantity and Quality Sources at Selected Percentages of Quantity Production and for Selected Levels of Quality**

| Operator Error Rate | Percent of Operating Standard | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 70 | | | | 80 | | | | 100 | | | | 120 | | | | 130 | | | | | | | |
| | Quan. | QUALITY | | Bonus | Quan. | QUALITY | | Bonus | Quan. | QUALITY | | Bonus | Quan. | QUALITY | | Bonus | Quan. | QUALITY | | Bonus | Quan. | QUALITY | | Bonus |
| p (%) | (5) | (3) | (4) | Total | (5) | (3) | (4) | Total | (5) | (3) | (4) | Total | (5) | (3) | (4) | Total | (5) | (3) | (4) | Total | (5) | (3) | (4) | Total |
| 0.0 | -2.00 | 4.46 | 3.24 | 5.70 | 0.00 | 5.10 | 3.70 | 8.80 | 4.00 | 6.37 | 4.63 | 15.00 | 8.00 | 7.65 | 5.56 | 21.21 | 12.00 | 8.28 | 6.02 | 26.30 | | | | |
| 0.1 | -2.00 | 4.17 | 2.95 | 5.12 | 0.00 | 4.76 | 3.37 | 8.13 | 4.00 | 5.95 | 4.21 | 14.16 | 8.00 | 7.14 | 5.05 | 20.19 | 12.00 | 7.74 | 5.47 | 25.21 | | | | |
| 0.2 | -2.00 | 3.87 | 2.67 | 4.54 | 0.00 | 4.43 | 3.05 | 7.48 | 4.00 | 5.53 | 3.81 | 13.34 | 8.00 | 6.64 | 4.57 | 19.21 | 12.00 | 7.19 | 4.95 | 24.14 | | | | |
| 0.4 | -2.00 | 3.34 | 2.16 | 3.50 | 0.00 | 3.81 | 2.47 | 6.28 | 4.00 | 4.77 | 3.09 | 11.86 | 8.00 | 5.72 | 3.70 | 17.42 | 12.00 | 6.19 | 4.01 | 22.20 | | | | |
| 0.6 | -2.00 | 2.82 | 1.72 | 2.54 | 0.00 | 3.22 | 1.97 | 5.19 | 4.00 | 4.02 | 2.46 | 10.48 | 8.00 | 4.83 | 2.95 | 15.78 | 12.00 | 5.23 | 3.20 | 20.43 | | | | |
| 0.8 | -2.00 | 2.33 | 1.34 | 1.67 | 0.00 | 2.67 | 1.53 | 4.20 | 4.00 | 3.33 | 1.91 | 9.24 | 8.00 | 4.00 | 2.30 | 14.30 | 12.00 | 4.33 | 2.49 | 18.82 | | | | |
| 0.9 | -2.00 | 2.10 | 1.17 | 1.27 | 0.00 | 2.40 | 1.34 | 3.74 | 4.00 | 3.00 | 1.67 | 8.67 | 8.00 | 3.60 | 2.01 | 13.61 | 12.00 | 3.89 | 2.17 | 18.05 | | | | |
| 1.0 | -2.00 | 1.88 | 1.01 | 0.89 | 0.00 | 2.15 | 1.16 | 3.31 | 4.00 | 2.69 | 1.44 | 8.13 | 8.00 | 3.22 | 1.73 | 12.95 | 12.00 | 3.49 | 1.88 | 17.37 | | | | |
| 1.1 | -2.00 | 1.66 | 0.87 | 0.53 | 0.00 | 1.90 | 0.99 | 2.89 | 4.00 | 2.37 | 1.24 | 7.61 | 8.00 | 2.85 | 1.48 | 12.33 | 12.00 | 3.09 | 1.61 | 16.70 | | | | |
| 1.2 | -2.00 | 1.45 | 0.73 | 0.18 | 0.00 | 1.65 | 0.84 | 2.49 | 4.00 | 2.06 | 1.05 | 7.11 | 8.00 | 2.48 | 1.26 | 11.74 | 12.00 | 2.68 | 1.36 | 16.04 | | | | |
| 1.4 | -2.00 | 1.06 | 0.49 | — | 0.00 | 1.21 | 0.56 | 1.77 | 4.00 | 1.51 | 0.70 | 6.21 | 8.00 | 1.81 | 0.84 | 10.65 | 12.00 | 1.96 | 0.91 | 14.87 | | | | |
| 1.6 | -2.00 | 0.68 | 0.30 | — | 0.00 | 0.78 | 0.34 | 1.12 | 4.00 | 0.97 | 0.42 | 5.39 | 8.00 | 1.17 | 0.51 | 9.68 | 12.00 | 1.26 | 0.55 | 13.81 | | | | |
| 1.8 | -2.00 | 0.33 | 0.13 | — | 0.00 | 0.38 | 0.15 | 0.53 | 4.00 | 0.47 | 0.19 | 4.66 | 8.00 | 0.57 | 0.22 | 8.79 | 12.00 | 0.61 | 0.24 | 12.85 | | | | |
| 2.0 | -2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.00 | 0.00 | 0.00 | 4.00 | 8.00 | 0.00 | 0.00 | 8.00 | 12.00 | 0.00 | 0.00 | 12.00 | | | | |
| 2.5 | -2.00 | — | — | — | 0.00 | — | — | — | 4.00 | Less | 10% | 3.60 | 8.00 | Less | 10% | 7.20 | 12.00 | Less | 10% | 10.80 | | | | |
| 3.0 | -2.00 | | | | 0.00 | | | | 4.00 | Less | 30% | 2.80 | 8.00 | Less | 30% | 5.60 | 12.00 | Less | 30% | 8.40 | | | | |
| 3.5 | -2.00 | | | | 0.00 | | | | 4.00 | Less | 60% | 1.60 | 8.00 | Less | 60% | 3.20 | 12.00 | Less | 60% | 4.80 | | | | |
| 4.0 | -2.00 | | | | 0.00 | | | | 4.00 | Less | 100% | 0.00 | 8.00 | Less | 100% | 0.00 | 12.00 | Less | 100% | 0.00 | | | | |



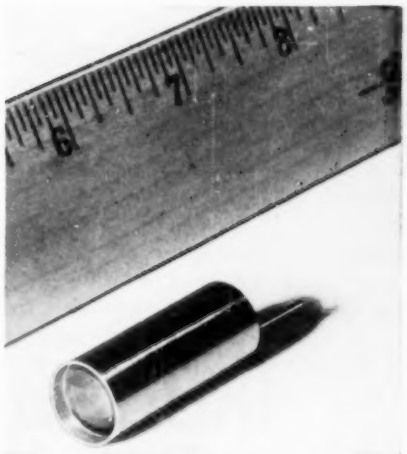
Checking perforated metal card in Bell's new "card file" which uses Phototransistors to help route Long Distance telephone calls along the best routes. If the first voice-way is in use, a "detour" is swiftly found. The equipment is known in telephony as a "card translator."

# CARDS FOR CONVERSATION

To find out how to route Long Distance calls a dial system needs lots of information—fast. To provide it Bell Laboratories engineers developed a new kind of card file—one that dial systems can read.

Punched holes on metal cards tell how calls should be handled. When a call arrives the dial system "asks" the "card file" how to proceed to a particular area. Instantly the appropriate instruction card is displaced so that its pattern of holes is projected by light beams on a bank of Phototransistors. In a flash the Phototransistors signal switches to set up the best connection. Cards are quickly changed when new instructions are needed.

The "card file" will have its widest use in speeding Long Distance calls that are now dialed by a telephone operator and may one day be dialed by you personally. It is another example of how Bell Telephone Laboratories helps telephony to grow, as costs are kept down.



New Phototransistor unit. Light entering the cylinder is focused by the lens on a piece of germanium that responds by generating current. Like the Transistor, the Phototransistor was invented in Bell Telephone Laboratories.

BELL TELEPHONE LABORATORIES

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(80 percent of standard production), and also, she may lose some, or all, of her quantity bonus if the quality for that week is bad (more than two percent). Thus the plan would establish a double deterrent to producing quantity at the expense of quality.

The current quantity incentive plan is given by the graph in Fig. 1. Pay Rate gives the percentage of base pay received (never less than 100 percent) and Operating Rate gives the percentage of standard production which the operator has attained for the week.

As used at present the Pay Percent (M) is given in terms of the Operating Percent (W) by the following functional relations:

$M = 100\%$ (base pay); $W \leq 80\%$*
$M = 0.5W + 60$; $80\% \leq W \leq 120\%$
$M = W$; $120\% \leq W$

*The percentages here are based on Standard Production = 100%.

For the proposed plan, it is suggested that this quantity incentive be modified as follows to allow for an overall bonus to an operator who performs accurately, even though somewhat below norm (80% of Standard) quantity-wise:

$M = 0.5\,W + 60$; $0\% \leq W \leq 120\%$
$M = W$; $120\% \leq W$

This is used with the understanding that the combined quality and quantity adjustment shall not be negative; that the gross pay for the week shall never be less than the employee's base rate.

Table II gives the necessary numerical details for operating the proposed plan on the basis of the following assumptions:

1. The operator's unit of work is 150 plates
2. The standard rate of production (100 percent operating performance) is 71.5 plates per hour
3. The operator's base pay is $40.00 per week
4. The cost of inspection is one cent per plate, based on direct labor and supervision
5. The cost of adjusting a complaint or request is $0.65, same basis as in (4)
6. The basic (reference) error rate is taken as two percent and all quantity bonus is wiped out if error rate for the given week is found to be four percent or over as shown by the samples taken on the basis of the Dodge-Romig SA-1.0 plan.
7. The percentage of deduction (D) is a quadratic function of the error rating; for $2 \leq p \leq 4$, $D = 20p^2 - 70p + 60$ such that $D = 0$ for $p = 2$ and $D = 100\%$ for $p = 4$.

The table shows contributions and total bonus (in dollars) for quantity (Formula 5) and quality (Formulas 3 and 4) considerations based on the above assumptions.

Calculations have been made for typical percentages of Operating Standard (70, 80, 100, 120, 130) and selected values for Operator Error Rate, p.


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# Industrial Quality Control

THE MAGAZINE THAT IS **READ** BY THE MEN WHO WILL **USE** YOUR PRODUCT!

For Rates and Space Address Your Inquiry to George R. Foster,
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# 85% *Reduction in* GAGE COSTS

*Originators of Reversible Thread Gages*

| No. of Holes Gaged | Cost of Regular AGD Unplated Plug Gages | Cost of Reversible Chrome Plated Size Control Plug Gages |
|---|---|---|
| 10,000 | 10 @ $10.00 Total $100.00 | 1 @ $15.00 Total $15.00 |

Figures based on 1000 holes per regular AGD unplated gage before end worn undersize. Size Control Chrome Plated Reversible Plug Ends give 10 times that service.

## YOU SAVE WITH SIZE CONTROL REVERSIBLE PLUG GAGES

Reduce plug replacement costs . . . reduce possibilities for passing sub-standard parts—you save two ways with these longer lasting Size Control Gages. Available in plain or chrome plated steel, Norbide, and tungsten carbide. Send for catalog 53. It describes these and other money-saving quality gages.

***Reversible Plugs*** — plain or threaded they reverse quickly in pin-vise handle to give double service. Worn tips can be cut off at each end and new sections exposed for six-fold service.

***Entire Plug Surface Useable*** — straight, untapered pieces provide uniform gaging surface over entire length — finished to 1½ microinches or less for maximum gage life.

***Pin-Vise Aluminum Handle*** — positive locking; plugs can't slip. Easily loosened for replacing or reversing plugs — plug length adjustable for different hole depths.

***2 Gages in 1*** — double end saves time in all gaging operations. GO end green finish; NO-GO, red, for fast, easy recognition.

## OTHER SIZE CONTROL CO. Extra Values!

(1) Truncated Thread Set Plugs—give greater value.

(2) Thread Ring Gages root relieved on major diameters permit more resets.

(3) Carbide and Chrome Gages and Measuring Wires.

(4) Plug gages up to .125" furnished in high speed steel at no extra cost.

## PRECISION PLUS PRODUCTION-WITH CENTERLESS LAPPING

Size Control's new Centerless Lapping Machine gives a precision finish of 1½ micro inches or less to cylindrical parts. Requires no special operating skill—piece is simply placed between lapping rolls. No costly set-ups or special tools — handles diameters from .010" to 10.00" with speedy adjustment of roller spacing. Send for Catalog 53.

## SIZE CONTROL COMPANY

2500 W. WASHINGTON BLVD. MONROE 6-6710 CHICAGO 12, ILLINOIS

*Division of*

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ENGINEERING REPRESENTATIVES IN PRINCIPAL CITIES

***The Finest Gages Made***

# A Simplified Control Chart for the Job Shop

HARVEY E. MAXWELL

**Caterpillar Tractor Company**

The application of $\bar{X}$, R charts to processes, where productivity requirements necessitate infrequent job changes, has the normal problems related to charting. However, if a manufacturer's product is greatly diversified with the many resultant job changes for each machine, then the problems increase many times.

The Statistical Quality Control Section, of Caterpillar Tractor Co., was faced with such a dilemma because of diversification of product. This article describes the problems encountered as our program developed from its inception, with the solutions resolved for specific problems which culminated in the design of a cell chart for charting variability. This cell chart made it possible to have but one chart per machine on which all parts and all tolerances processed could be controlled.

At the start of our program, recognizing that the quality of the product is determined by the processing, we concluded that the product quality of our processing shops would be assured if we controlled all the finishing processes. We first attempted to place a complete line under $\bar{X}$, R Chart Control by charting piece parts by part number. We were soon compelled to take cognizance of an intolerable situation because there were approximately one hundred different piece parts involved on which external grinding was done. The capacity of the grinders, relative to size of piece parts, was such that half of the product might be processed over each machine; there, it was obvious that hundreds of charts would be needed for several machines. Too, manufacturing supervision could never get a clear picture of the machine's processing capabilities because charts were continually being changed at job changes.

It was then concluded that inasmuch as all finishing processes were controlled, the part number was insignificant, and that the end result would be the same if the machines were charted. However, this approach to the problem was not completely satisfactory because a chart was required for each tolerance being processed over a machine. The burden of reproducing replacement charts was a constant annoyance requiring many thousands of hours, yearly; further, this work to reproduce replacements had no lasting benefits. It was then decided that we would put up master charts, to be contained in envelopes having a "Vu Pak" isinglass facing, and record the data on this isinglass facing with a special marking pencil. When the charts were filled, they could then be erased. The important data, when taken, were posted to a data sheet so that nothing was lost by this principle.

However, the over-all adaptation of this method was impossible because we still had as many as 15 charts per machine. At each job change to a different tolerance, one chart would be filed and another pulled out, with the result that the postings on the "Vu Pak" were obliterated.

At this point consideration was given to the idea of "cell charting," with each cell representing 0.1 of all tolerances. The decision to let each cell represent 0.1 of tolerance was conceived as being logical, because it is recognized that in checking variability the increment of measure which portrays the best picture is 0.1 of tolerance.

The "cell chart" for variability charting is constructed by ruling off both the average and range sections of the chart into ten cells which define all specification boundaries.

Figures 1 and 2 illustrate reproductions of a chart and of a data sheet in actual use. Five samples are plotted on each of three toler-

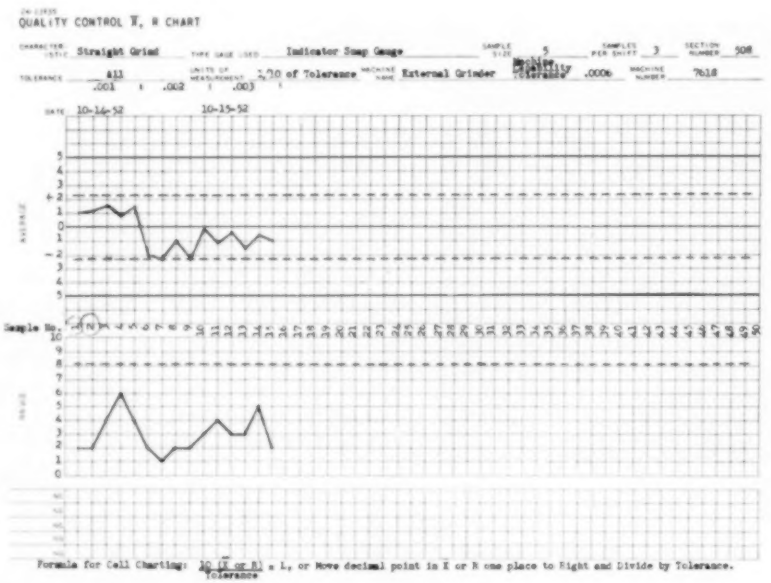

QUALITY CONTROL X̄, R CHART
Straight Grind
Indicator Snap Gauge
External Grinder
10-14-52
10-15-52
Sample No.
Formula for Cell Charting: 10 (X̄ or R) = L, or Move decimal point in X̄ or R one place to Right and Divide by Tolerance.

Figure 1

ances, which are ±0.0005, ±0.001, and ±0.0015. The chart and data sheet are applied as follows: Measurements and calculations of $\bar{X}$, R factors are made in the conventional way, the increment of measure used being 0.1 of tolerance. The measure used and calculation of $\bar{X}$, R is, however, not reflected in the cell chart until the conversion is made to $\bar{X}$ cell and R cell. The formula $\frac{10\ (\bar{X}\text{ or }R)}{T} = L$ where T is the tolerance and L is the cell line, is fundamental when each cell on the chart equals 0.1 of all tolerances.

The details for converting to cell values are as follows:

(1) The five measurements comprising the first sample of the ±0.0005 tolerance were averaged and the range recorded in the conventional manner. Results: $\bar{X} = +0.0001$, $R = 0.0002$

(2) The resultant $\bar{X}$ is converted into cells for charting by multiplying by ten and dividing by the total tolerance.

$$\bar{X} = \frac{10\ (+0.0001)}{0.001} = +1.0 \text{ cell}$$

This formula is derived from the fact that all $\bar{X}$ values are to be plotted in *cells* and each cell equals 0.1 of the total tolerance. To check this, note that the cell interval necessary to divide the total tolerance into ten parts is: $\frac{0.001}{10} = 0.0001$. Inasmuch as the $\bar{X}$ is just +0.0001, it is exactly 1.0 cell above zero.

(3) The range is converted into cells for charting by the same formula.

$$R = \frac{10\ (0.0002)}{0.001} = 2.0 \text{ cell}$$

(4) The points are now plotted on the chart, the $\bar{X}$ on the "+1" line for averages and the R on "2" line for ranges.

The control chart is put up at the machine after a study has been made to determine the tighest tolerance which it can be expected to hold. This is called the "machine capability tolerance" and is determined by converting the average range of a control chart (in original units, not cell units) to an estimate of $6\sigma'$, the machine capability. This machine capability tolerance is shown at the top of the chart so that everyone in the manufacturing setup will understand the machine's true capability and will not allocate work to that machine unless it is basically capable of meeting the specifications required.

The calculation of limits for the cell chart is extremely simple and, indeed, reflects one of its' chief advantages. So long as the sample size is kept constant, the limits will remain constant regardless of the tolerance to which the machine is working. This may be seen by the following procedure for obtaining the control limits for samples of five.

(1) Assume that the spread of the process occupies the full tolerance range. This is equivalent to saying that we are willing to accept a process having a capability equal to the tolerance. This is perfectly valid if the "machine capability tolerance" is respected, as previously indicated.

(2) Since all tolerances are exactly ten cells, this means that $6\sigma' = 10$ cells.

(3) Since $\sigma' = R/d_2$, we may write: $6R/d_2 = 10$ (cells) whence:

$$\bar{R} = \frac{10d_2}{6} = 1.67d_2 \text{ cells}$$

This is the maximum average range which will be acceptable.

(4) To compute control limits for $\bar{X}$, we use the conventional formula with $A_2 = 0.58$, $d_2 = 2.33$, and substitute the above value for $\bar{R}$ in it:

$$CL_{\bar{X}} = \bar{\bar{X}} \pm A_2\bar{R}$$
$$= 0 \pm (0.58)(1.67)(2.33)$$
$$= \pm 2.26 \text{ cells.}$$

(5) The control limit for range is computed similarly:

$$UCL_R = D_4\bar{R}$$
$$= (2.11)(1.67)(2.33)$$
$$= 8.21$$

It can thus be seen that all cell charts for samples of five have the same control limits regardless of the tolerance or the actual capability. In effect, this means that, when the machine capability tolerance actually is equal to the total tolerance required, the limits will be exactly the same as those for an ordinary control chart. When it is less than the total tolerance, the limits will be effectively wider than conventional limits, even though they appear to be the same on the chart. But these wider limits under such conditions are justified by the fact that they permit the op-

ZH-14239

DATA SHEET FOR $\bar{X}$, R CELL CHART — INSPECTION DIV. QUALITY CONTROL SECTION

| | | | | | |
|---|---|---|---|---|---|
| 1ST SHIFT INSPECTOR | Warburton | 2ND SHIFT INSPECTOR | Beetler | 3RD SHIFT INSPECTOR | Bayless |
| CHARACTERISTIC | Straight Grind | TYPE GAUGE USED | Indicator Snap Gauge | UNIT OF MEASUREMENT | 1/10 of Tol. |
| DATE STARTED | 10-14-52 | SAMPLES PER SHIFT | 3 | MACHINE NO. | 7618 |
| DATE COMPLETED | 10-15-52 | SAMPLES SIZE | 5 | SECTION NO. | 508 |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| TOLERANCE | ±.0005 | ±.0005 | ±.0005 | ±.0005 | ±.0005 | ±.001 | ±.001 | ±.001 | ±.001 | ±.001 |
| | +.0001 | +.0001 | -.0001 | +.0002 | +.0002 | -.0004 | -.0004 | 0 | -.0004 | +.0002 |
| | +.0001 | +.0002 | +.0002 | +.0001 | -.0001 | -.0004 | -.0006 | -.0002 | -.0006 | +.0002 |
| | +.0002 | 0 | +.0002 | +.0004 | +.0003 | -.0002 | -.0004 | 0 | -.0006 | 0 |
| | 0 | +.0002 | +.0003 | -.0001 | +.0002 | -.0004 | -.0004 | -.0004 | -.0002 | -.0002 |
| | +.0001 | +.0001 | +.0002 | -.0002 | +.0001 | -.0006 | -.0004 | -.0004 | -.0004 | -.0004 |
| $\bar{X}$ | +.0001 | +.00012 | +.00016 | +.00008 | +.00014 | -.0004 | -.00044 | -.0002 | -.00044 | -.00004 |
| R | .0002 | .0002 | .0004 | .0006 | .0004 | .0004 | .0002 | .0004 | .0004 | .0006 |
| $\bar{X}$ CELL | +1 | +1.2 | +1.6 | +.8 | +1.4 | -2 | -2.2 | -1 | -2.2 | -.2 |
| R CELL | 2 | 2 | 4 | 6 | 4 | 2 | 1 | 2 | 2 | 3 |

| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| TOLERANCE | ±.0015 | ±.0015 | ±.0015 | ±.0015 | ±.0015 | | | | | |
| | -.0006 | +.0003 | -.0009 | -.0012 | -.0006 | | | | | |
| | -.0009 | -.0003 | -.0009 | 0 | 0 | | | | | |
| | +.0003 | 0 | -.0003 | 0 | -.0003 | | | | | |
| | +.0003 | 0 | -.0003 | +.0003 | -.0003 | | | | | |
| | -.0009 | -.0006 | 0 | 0 | -.0003 | | | | | |
| $\bar{X}$ | -.00036 | -.00012 | -.00048 | -.00018 | -.0003 | | | | | |
| R | .0012 | .0009 | .0009 | .0015 | .0006 | | | | | |
| $\bar{X}$ CELL | -1.2 | -.4 | -1.6 | -.6 | -1 | | | | | |
| R CELL | 4 | 3 | 3 | 5 | 2 | | | | | |

| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| TOLERANCE | | | | | | | | | | |

Figure 2

erator of the machine to utilize the full tolerance still without producing defective work.

It is recognized that this does not conform to true statistical quality control theory, where capability tolerances are determined by a study of each process, and the control limits are calculated from these data. However, the aim of this chart is to secure product to specifications by providing a practical method of charting all processes economically, with very little sacrifice of the benefits gained through conventional charting. Actually, where job changes are frequent, the capability tolerance will be demanded often, and the probability of an assignable cause of any magnitude developing is remote. A specific advantage is gained by using constant control limits because they are always relative to specification boundaries for specific sample size, whereas, when calculated from capability data, they rarely are.

When those responsible for quality know that the controls give them everything possible to produce product to specifications, they have respect for them; however, when the controls are calculated from capability studies, and some charts are found more restrictive than others, such respect is difficult to obtain. Certainly, to restrain production and search for an assignable cause when controls are restrictive is uneconomical. Any enterprise today is burdened by statistics, and certainly we do not want to impose any which are unnecessary, for any reason whatsoever.

It is obvious that when the processing capabilities of a machine and the specification limits are the same, then the constant control limits used are accurate in a true statistical sense. It is also apparent that when the specification limits are greater, several additional standard deviations would be permitted by using constant control limits. However, rarely will this additional latitude be as calculated because the demands made on the chance cause factors, by change in piece part size, tolerance specified, production requirements, finish, etc., do not remain constant factors.

Specifically, a parameter, estimated for a process that meets the most restrictive tolerance, can not be used directly in calculating control limits for less restrictive tolerances.

The most restrictive tolerance, which could be processed by the external grinder of Fig. 1, was ± 0.0003 and this tolerance "fits" a certain combination of variables. The processing of other, less restrictive, tolerances will always result in different combinations of variables. Hence there will be a change in the resultant variability. However, our experience indicates that rarely will this change in the combination of variables, result in a process running out of control. This is because certain variables, such as the operator, the machine, the coolant, etc., tend to remain fairly constant.

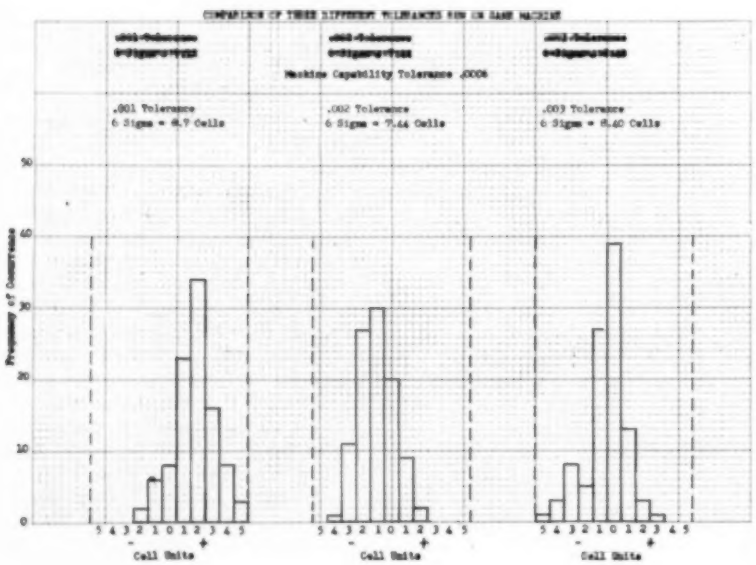
Figure 3 illustrates frequency distributions and standard deviation calculations for three tolerances processed over a machine which has a capability tolerance of ± 0.0003; it reflects the preceding comments. In this illustration ten cells represent tolerances of ± 0.0005, ± 0.001, and ± 0.0015. Note that, for the ± 0.0005 tolerance, the process capability was 8.7 cells, or 0.00087. For the ± 0.001 tolerance, it was 7.44 cells, or 0.001488 and for the ±0.0015 tolerance, it was 8.40 cells, or 0.0025.

To summarize — the most restrictive tolerance that could be effectively processed was ± 0.0003, and ten cells on the $\bar{X}$, R Chart represent this tolerance. The ± 0.0005, ± 0.001 and ± 0.0015 tolerances, to be produced, are also represented by ten cells. The process tolerances were as indicated, which resulted in product for these different tolerances being to specification when processed under control.

It may be noted, in referring to the histograms in Fig. 3, that, as the tolerances for product become less restrictive, the natural tolerance of the process does not necessarily keep in direct step with it. Natural tolerance is rather the result of the inherent capability of each process.

The constant control limits, therefore, do not allow the latitude which we first assumed. In this particular illustration, the constant control limits result in only a margin of safety on processes which have tolerances less restrictive than the most restrictive tolerance the machine can produce. Also referring to the cell chart, note the plotting pattern developed relative to the constant control limits on these tolerances.

It is necessary to determine the best processing capability of a machine, but to use these data for calculating control limits to be applied to all tolerances would, in most cases, be incorrect and result in uneconomical manufacture. Actually, it would be necessary to make a



capability study of every process to be processed over each machine if charting were done in a true statistical sense. This would be most prohibitive and curtail the application of Statistical Quality Control to our processes.

It is not the intent herein, to recomend the cell-chart tool for variability as replacing the Shewhart chart, but it is believed that the practical concepts and the technical aspects of the basic fundamentals of the Shewhart chart can be combined to get the job done.

The benefits we are deriving from this method of charting are many. The Quality Control Section saves untold thousands of hours of typists' time in reproducing charts, the quality control analysts in replacing charts, the line inspectors in changing charts at job changes. Furthermore, the production supervisor now has a continuous picture of each machine.

To the Statistical Quality Control Section, of Caterpillar Tractor Co., the charting of variability by this method has been the answer to diversified product and its many setups and short-runs.

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# Problems Department

**PAUL C. CLIFFORD, Editor**

*Problems for solution, and correspondence concerning material published in this department, should be addressed to*
PAUL C. CLIFFORD
39 Norman Rd.
Montclair, N. J.

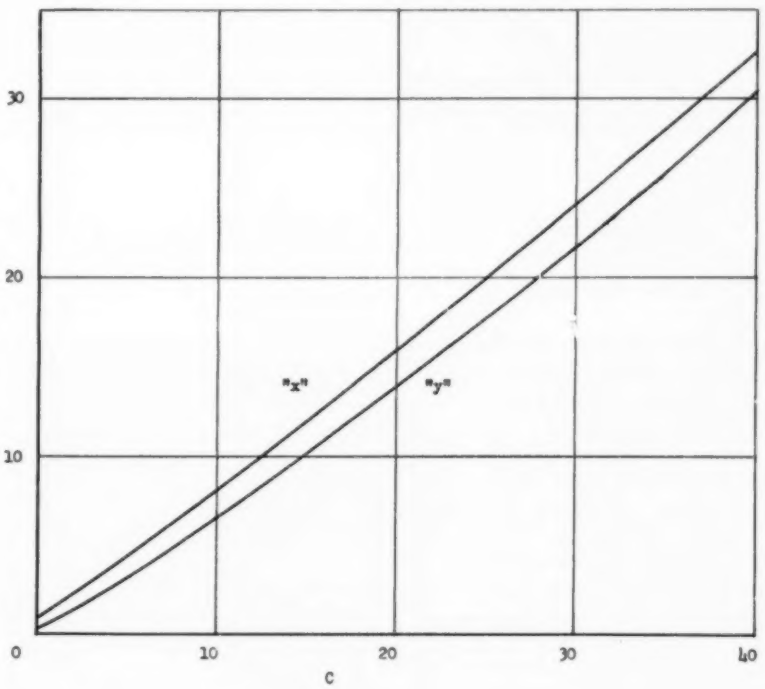
## SAY IT AGAIN

Sometimes we dont talk so good—or write so good either. Problem 8, in the May 1953 issue of IQC is an example. George V. Herrold of Sylvania Electric Products, Huntington, W. Va. sent in a suggested solution. For some reason we did not like it. We found the reason when we read the problem over again.

In operating a single sampling plan with $c = 0$, there is a natural tendency to cease inspection as soon as a defective has been observed. The disposition of the lot is correct, but it is somewhat difficult to estimate the average percent defective in submitted lots. In the example quoted the sampling plan in use was $n = 50$, $c = 0$. Three lots had passed this sampling plan, and two had failed. On the first of these two lots the defective had been observed on the 6th trial. On the second lot the defect had been observed on the 39th trial. The important point is that the percent defective in these rejected lots cannot be estimated as the reciprocal of the number inspected, because of the truncation that takes place when the defect is encountered.

Your editor rather obstinately refuses to give solutions for problems. Mostly this is to give himself a perfect alibi on the question as to whether or not he has a solution. However I am quite willing to state that this apparently simple problem is one for which I have no satisfactory solution. I thought that C. C. Craig's "Note on the Use of Fixed Numbers of Defectives and Variable Sample Sizes in Sampling by Attributes," which also appeared in the May 1953 issue of IQC might have a solution. However in our problem we do not continue to sample until we find a defect. It might be worse if we did. For using Professor Craig's notation, the quantity $\frac{m-1}{n-1}$ is an "unbiased" estimate of p. In this case it is also a useless estimate, since $m - 1$ is zero if a defect is encountered. Some biased but more useful estimate is needed. Your editor ceased being an "expert" when he left India, but this is a public call for the statistjcians' help. How about a nice neat solution?

My own procedure has been to base an estimate of p on the percent of lots that are accepted. Three out



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of five lots have been accepted. This is what we would expect if we used the Poisson distribution with $a = 0.5$, giving $p = 0.01$. This does not utilize the information as to when the defect occurred, and so it would seem that some more efficient estimate could be formulated. Complete inspection of the sample would seem a high price to pay for the usual estimate.

### WILL I ALWAYS WONDER

While I am at it I might add a word about the source of problems. It has surprised me that all the problems that have been published in these columns have come from industry—from the quality control operators, as they have been called. None have come in from the classrooms. This has not been true of the solutions, many of which have been from the colleges. But it makes it appear that all is clear, calm and serene in the halls of ivy. Personally I do not believe a word of it. So just to prove I am right, how about you professors having some of those problems written up and submitted?

### WALTZ ME AROUND AGAIN, WILLIE

We will take the blame for this mix-up, for the way our copy goes in it is surprising that our good friend Mason Wescott puts up with us. However there was a misplaced page somewhere in the May issue that we should correct. The last ten lines of column 2, all of column 3 and the first 6 lines of column 4 should have come after the first five lines of column 5. Not that our feelings are hurt, and in some ways it was more fun as it stood. Sort of had the feeling that it was really becoming a problem department. However it was a little rough on Mr. King to use random assembly in this case. And if nothing else it proves that there is at least one reader—the editor.

### PROBLEM 9. SUGGESTED SOLUTIONS

This problem concerned simple estimates of the AOQL of a single sampling plan, given n and c with n/N small and the Poisson as a suitable distribution function. Replies were received from Frederick W. Cleaver, College of Engineering, Cornell University and from George V. Herrold. Both point out that Table A (page 49) of the Dodge-Romig Sampling Tables give values of "y" for $c = 0$ (1) 40. Dodge and Romig

define $y = \frac{e^{-x} x^{c+2}}{c!}$ and show that the AOQL $= y\left(\frac{1}{n} - \frac{1}{N}\right)$. When n/N is small, a close approximation to the AOQL would be y/n.

This same table gives values of "x" where $x = p_1 n$, $p_1$ being the percent defective at which the AOQL is attained. If the tabulated values of either y or x are plotted against c, the resulting graph is slightly concave upward as shown in Fig. 1. The values of both x and y might be well approximated by a parabola, and your editor hopes that someone with computation equipment might do this. Some crude results that are fairly satisfactory can be obtained by linear approximations. If n/N is small these approximations are

| c | $p_1$ | AOQL |
|---|---|---|
| 0 — 5 | $\frac{0.67c + 3}{n}$ | $\frac{0.56c + 0.4}{n}$ |
| 5 — 10 | $\frac{0.75c + 0.55}{n}$ | $\frac{0.67c}{n}$ |
| 10 — 40 | $\frac{0.80c}{n}$ | $\frac{0.76c - 1}{n}$ |

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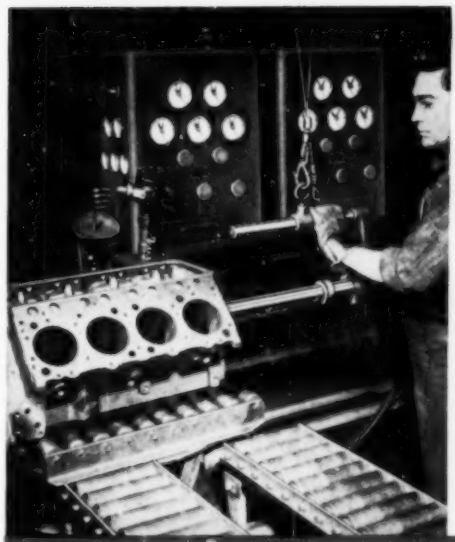
... in the Automotive Industry



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# From the Scrap Box

*Contributions for the Scrap Box Department should be addressed to: Prof. Mason E. Wescott, Chairman, Editorial Board, University College, Rutgers University, New Brunswick, N. J.*

To the Editor,
Industrial Quality Control:

Prof. C. C. Craig's article discussing the lot plot acceptance inspection plan in the September *Industrial Quality Control* highlights the interest which exists regarding the technical foundations of the plan and its proven effectiveness in wide industrial usage. Prof. Craig discusses three phases:

(a) The misuse of lot plot for process control.

(b) The operating characteristic of lot plot and its tendency to reject borderline good lots.

(c) The dependence on histograms.

The first point requires no further comment. Lot plot is an *acceptance* inspection plan, not a process control plan.

The second point is a deliberate feature of lot plot which was initially developed for the aircraft industry. The critical nature of this industry requires that mechanical routines be used to accept only those lots which are *unquestionably good*. Borderline lots do and must require special attention. This special attention is and must be tailored to the problem at hand—it cannot be a routine matter. Previous to lot plot, painful experience showed that too many lots given 100 percent inspection were either still borderline or were even seriously defective. They were not receiving the special attention they required.

For non-critical industries, it would be a simple matter to modify lot plot to estimate the 2.5-$\sigma$ or even 2-$\sigma$ lot limits. Surprisingly, this is seldom done. Widespread use of lot plot in non-critical industries has shown that its tight operating characteristic is very helpful in obtaining firm control over quality.

The third point considers a misconception very widely existing particularly among those who have not personally used lot plot in actual factory operations. Lot plot is *not* dependent on production being from a controlled process. Its purpose is to pass judgment on *all* lots received. Lots from uncontrolled processes are and always will be received, and these lots must be judged correctly.

The purpose of lot plot is to estimate the *true lot limits*, not the form of the population distribution. True, the *apparent* form as revealed by a frequency distribution of 50 random pieces is used in selecting the rule for lot limit calculation. But what happens when the apparent form differs from the true population form? Nothing serious. The judgment of population form is subject to the same type of sampling errors as judgment of the population mean and spread. Lot plot was very carefully devised to minimize the effect of these sampling errors on the calculated lot limits. Prof. Craig's eleven bimodal examples illustrate this point vividly. (Of course, samples for the last four are not strictly random samples.) Estimated lot limits for these examples are given in Table A. Seven of the lot plots showed the true bimodal form of the population. In no case does the estimated lot limit differ from the true lot limit by more than 12 percent of the population spread. This accuracy is sufficient for industrial purposes because:

**TABLE A—Estimated Lot Limits for Prof. Craig's Eleven Bimodal Lots**

| Example Number | Estimated Lot Limits | | Deviations from True Limits | | Population Spread *Percent* | |
|---|---|---|---|---|---|---|
| | *U* | *L* | *U* | *L* | *U* | *L* |
| *Bimodal Lot Plots* | | | | | | |
| 1 | 4.4 | 6.2 | −0.8 | −1.0 | −6 | −8 |
| 3 | 4.5 | 6.7 | −0.7 | −0.5 | −6 | −4 |
| 6 | 3.7 | 8.9 | −1.5 | −1.3 | −12 | −10 |
| 7 | 7.1 | 9.7 | +1.9 | −0.5 | +12 | −3 |
| 8 | 5.7 | 10.5 | +0.5 | +0.3 | +3 | +2 |
| 9 | 4.1 | 11.1 | −1.1 | +0.9 | −7 | +6 |
| 10 | 4.5 | 10.7 | −0.7 | +0.5 | −5 | +3 |
| 11 | 4.5 | 10.5 | −0.7 | +0.3 | −5 | +2 |
| *Normal Lot Plots* | | | | | | |
| 2 | 5.6 | 8.5 | +0.4 | +1.3 | +3 | +10 |
| 4 | 7.8 | 11.9 | +2.6 | +1.7 | +17 | +11 |
| 5 | 7.8 | 12.0 | +2.6 | +1.8 | +17 | +12 |

(a) Even when tolerances are scientifically determined, they are not determined to this accuracy.

(b) Gaging inaccuracies are often of this magnitude.

(c) Cell widths used in tabulating the frequency distribution are of this magnitude.

Notice particularly the three examples where the lot plot did not reveal the bimodal nature of the population. In every case the estimated lot limits are conservative (wider than the true population limits). Even here the overstatement is a maximum of 17 percent of the population spread. Lot plot has treated these eleven lots very well indeed considering that the lots were deliberately from non-normal processes and that it is desirable to discriminate slightly against such processes.

Very truly yours,

*Dorian Shainin*

To the Editor,
Industrial Quality Control:

It appears that Mr. Shainin has interpreted my article as an attack on the lot plot plan. It is an attack on the misuse of that plan for process control, which I have the impression is rather widespread. Though Mr. Shainin agrees with me it seems to me that the fourth paragraph of his letter and the articles in the March 1952 IQC leave an ambiguous impression.

I agree that in ordinary cases the lot plot scheme is what it was designed to be, a severely effective sampling acceptance plan. I do feel that its severity should be more widely understood. I also tried to point out for our non-technical readers that our knowledge of the OC curve for this and other variable plans is rather limited and that some caution should be exercised in its use.

As for my third main point, I still object to inferring so much from the shape of histograms of samples of 50. This only reinforces the widespread tendency to rely too much on histograms in process control. As an acceptance plan I suspect lot plot would work about as well with a much less elaborate set of rules for "non-normal" plots. I wonder how faithfully this machinery is used in practice. As for the lot plot plan being distribution free, this kind of statement needs careful substantiation. In this connection my eleven lot plots are rather innocent examples. In seven of them the process was controlled and in the others, the two processes were.

I do not feel that the essential features of the lot plot acceptance plan were under attack in my paper.

Very truly yours,

*Cecil C. Craig*

## QUALITY CONTROL AND WAGE INCENTIVES

**RALPH O. SWALM**
**Syracuse University, Syracuse, N. Y.**

Do today's incentive wage plans promote high quality? Or are incentive wages, as some claim, incompatible with high quality standards? They shouldn't be—not if we agree with Albert Ramond, who said, in concluding an address on "The Philosophy and Practices of Wage Incentives:"[1]

"Wage incentive brings practical results. But it does much more than that. It encourages men to believe again that good work is meritorious and that it is recognized. A good wage incentive policy can do what no machines, no apparatus, and no technique can accomplish, for it inspires a purposeful attitude. It furthers a cooperative spirit and prompts better morale. In the final analysis it must be admitted that nothing in the world can substitute for man's belief in himself, and management should do everything in its power to build up that belief."

What industrial engineer would disagree with him? What captain of industry would dare label this doctrine false? It is noble, it is good—but it is seldom practiced.

It is seldom practiced because we have forgotten that there are at least two important factors that join to produce good work, and both should be present to encourage a man's belief in himself. One is quantity—and that we recognize in designing our incentive wage plans. The other is quality, and that we largely ignore. True, many incentive installations attempt to recognize it by stating that only "good" pieces will be paid for, but this pays little more than lip service to the principle that man's belief in himself should be promoted by encouraging him to take pride in the quality of his work. In the first place, it is too negative. It uses the big stick instead of the carrot. From a purely practical standpoint, it is often an impossible rule to administer because it is sometimes quite difficult to allocate responsibility. Was the bad part caused by defective material or defective workmanship? And if a lot is passed (perhaps using a sampling plan) by an inspector—is the worker still responsible for defects found later? Will such a policy ever have real meaning if each work station is not followed by 100 percent inspection?

Even granting 100 percent inspection and complete allocation of responsibility, a policy of not paying for poor work may fail to efficiently promote good work. An example of this from my own experience occurred, when, in molding refrigerator inner doors from laminated plastic, it was found that the labor cost for the molding operation was about three cents a door, whereas the material at that stage of production was worth over three dollars. Even though he knew that spoiled work would not be paid for, it was "good business" from the worker's viewpoint to speed up by ten percent, thereby increasing output from about 300 doors a day to 330, even though as a result of this haste an additional five doors were spoiled.

From the company's viewpoint, however, this additional output would be purchased at a very high price, since the additional spoilage would cost more than the worker was paid for the entire day's work. The control of this situation was made difficult by the fact that it was usually impossible to determine whether spoilage was caused by the operator's haste or by factors beyond his control; e.g. improperly cut or poorly impregnated paper.

This is not an isolated case—our former society president, Wade Weaver, has pointed out that a similar condition exists in sections of the steel industry—and it certainly represents one set of conditions under which a man's belief in the meritoriousness of good (quantity plus quality) work is not encouraged.

Then there are other ways in which a "pay for good work only" policy can be unfair. The more skilled a job, the more intricate the work, the harder to do a perfect job and the more likely the worker will be asked to spend a portion of his time for no remuneration.

Despite all these disadvantages we must affirm that the principle of paying only for good work is a start in the right direction—that of recognizing that good work implies both quantity and quality—but it is only a start.

How can we go further? Well, for one thing, we know from experience with ordinary piece-work type incentives what not to do. In this respect we are not like the golfer who, after searching for a lost ball for half an hour not only had failed to find the ball, but had also failed to ascertain where the ball was *not*. We know, from past experiences, several places where we will *not* find the "ball" we are seeking. We know that a proposal of the general type, "Pay a wage bonus of X cents per hour for each decrease of Y percentage points from present spoilage figures on each job," is unsound. Why? We have found from experience with incentive wage systems that which we could have known by logic—that standards based on past experiences are poor. They reward the previously inefficient worker and penalize the good worker. This, obviously, is fundamentally wrong, and cannot produce satisfactory results. Standards so established offer no solution for establishing a quality bonus on new jobs, except possibly to encourage the worker to do poor work during a trial period in order to earn a large bonus later.

Another approach that we have learned, through experience with incentive wage plans, to be poor, is to set standards based on present conditions with the expectation of tightening the quality standards as the

[1] Albert Ramond, "Philosophy & Practices of Wage Incentives." Reprinted from an address before the Industrial Relations Conference of the Radio Manufacturers Association, Pennsylvania Hotel, New York, N.Y., May 8, 1947.

workers improve the quality of output. The workers are quick to learn that, beyond a certain point, further improvement in quality will bring a reduction in earnings—and the obvious solution is to maintain the status quo. Time study engineers are still struggling to overcome the black eye given their science by indiscriminate rate cutting, and surely we can profit from their early mistakes.

In time study, we have found it necessary to arrive at a usable definition of normal pace and to find a workable means of judging deviation from that pace. By these means we are able to define the content of any job in terms of normal working time required to perform it. For a given method, this normal time is fixed and is measurable.

If we are to successfully design a quality incentive to supplement the usual quantity incentive, must we not do the same thing? Is it not necessary to first establish a working definition of "normal quality" and then devise a means of measuring deviations from that normal? Can this be done? Frankly, I don't know.

Up to this point, I have been on solid ground. In the golfing analogy, I am certain that it would be to our advantage to find the ball labeled "Quality Incentives." I am sure of some of the places where this ball will *not* be found. Beyond that, I can offer only questions, the discussion of which might lead to the actual finding of our desired "ball."

These questions cover two broad areas. First, "How shall we measure quality of work" and then "How shall we pay for superior quality of work?"

Would it be useful to define as "normal quality" an output which falls within 3-$\sigma$ control chart limits, or should we define this as "bonus quality," since this represents real achievement, and should bring with it some form of bonus? This basic approach has been suggested by Wharton.[2] But what of jobs not yet "in control"—should we treat them as the time study engineer does jobs on which the methods have not yet been standardized, and refuse to offer an incentive on them?[3]

How often should readings for the chart be taken? Should the narrowing of control limits bring with it a bonus? How much? What can we do for jobs not susceptible to control chart technique? Should we use X, R charts? What of p or c charts? Will such an approach be particularly useful in the situation where the responsibility is difficult to allocate?

How can we include a quality incentive in our wage scheme? Should it be a bonus of X cents per hour, or Y percent of base rate for good work? Should it operate to reduce the output required for standard pay? Should our base rate vary as quality of output varies? For example, should base rate for the next pay period be based in part on the quality in the present pay period? (Mr. E. W. Bickford has developed this general type of incentive to a high degree of success in the Chemical Department of the General Electric Company.)

This approach, which is an outgrowth of the measured daywork system, would seem to have great promise. Not only does it readily permit the combining of a quality and quantity bonus, but it lends itself particularly well to a situation in which the laws of chance operate. For example, if a bonus were given for each day that no point fell outside the 2-$\sigma$ control limits on an $\bar{X}$ chart, and samples were taken every hour, the worker might well react unfavorably when he saw his bonus vanish every few days, even though his quality remains unchanged. He may be treated perfectly fairly—having calculated that one point will fall out of the limits every 2½ days on the average, the quality bonus may be increased for the good days to compensate for this. But the psychology is still poor. The worker will be happier if his bonus for this week is predicated on something a little more stable—less subject to chance fluctuation. For example, the bonus might be paid if no more than five points in the last 100 had been out of control. In the course of a year he would receive no more money—but he would be more satisfied with the method of payment.

This general approach also seems to offer promise in the case where responsibility for bad work is difficult to allocate. If the bonus determining period is sufficiently long to give the laws of chance time to produce a reasonably stable system, we can base a bonus on "not more than X defects in the last Y days" and establish X as a function of the expected number of defects for a good operator.

Should quality bonus be on a non-financial incentive (additional vacation, special recognition, etc.,) rather than on a dollars and cents basis?

Perhaps these questions are premature. Surely our first concern must be with the possibility of establishing a useful bench-mark to be used in evaluating quality. Can this be done? Can our society sponsor research in this field? Should we have a committee to investigate applications of quality bonuses? Should we have a session concerning this at one of our annual meetings? In brief, where do we go from here?

[2] A. S. Wharton, "Quality Through Statistics," Phillips Lamps, Ltd., 1945

[3] Ray W. Good, "Quality Control in Relation to Time Study," *Industrial Quality Control*, Vol. IV, No. 2, Sept. 1943, pp. 13-16.

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A short while ago Fred Halton, Jr., assistant to the president of Deere and Company, sent along a talk on the history of the Mexico City Section of ASQC which was delivered by its national director, Domingo M. López, on the occasion of their fourth anniversary. It was felt that this story would be interesting to our readers, so it is published here substantially as it was written. Except for a few corrections, your editor resisted the normal impulse to make extensive changes because he felt that much of the flavor of the original story would be lost.

### Origin of the Section Ciudad de México

During the year 1944 were organized several talks on quality control, to prepare in that field the technicians of the Powder Plant at Santa Fe, D.F. The attendance was more than 15 persons, men and women. The results, due to local circumstances, were not as satisfactory as contemplated, nevertheless it was assumed that the effort was not in vain.

Early in 1949 the writer was asked to deliver a lecture for the benefit of the personnel of the government's Industrias Militares. On this occasion some of the engineering staff showed an interest in the subject and a Club was formed for the purpose of studying the techniques relating to quality control. The inauguration of the Club took place on March 25 of that year.

In June of the same year nine members of the Club became members-at-large of ASQC.

Our aim was to be recognized as a section of the Society, and in Septem-

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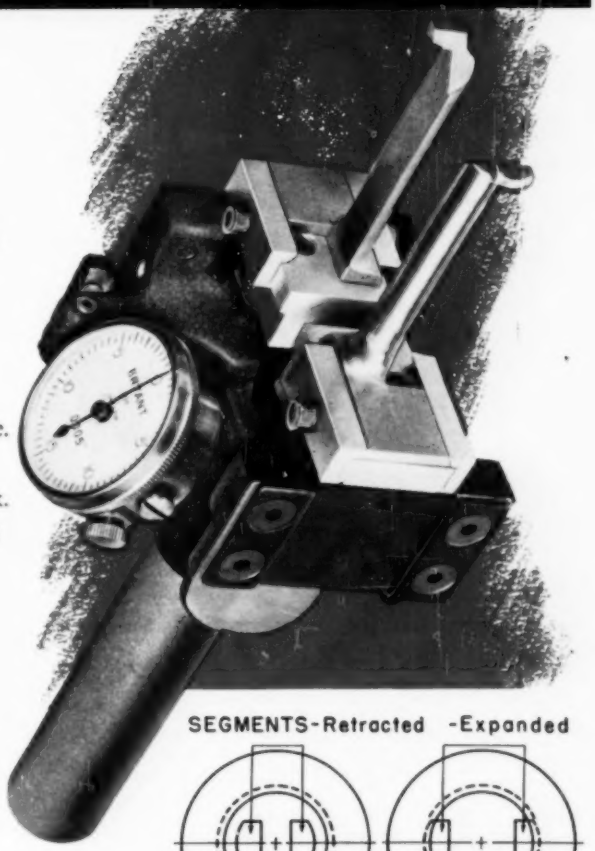
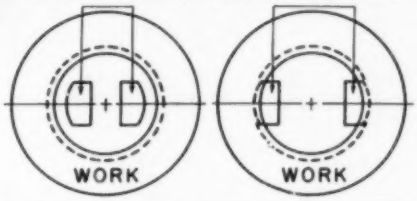


SEGMENTS-Retracted -Expanded

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ber a petition was sent to the headquarters office in New York. Unfortunately the statutes of the Society had been modified so that the number of members required to constitute a section were raised to 25; consequently we had to wait a little longer.

In March 1951 our Club received as a guest the distinguished professor and author, Eugene L. Grant. This good friend of ours on his return to his country must have given a favorable report to the then Executive Secretary, Simon Collier, regarding our organization and activities, because the result was that the Executive Committee authorized on September 8 the establishment of a section in the City of Mexico.

The Section accorded unanimously to offer the honorary presidency to Mr. Grant, which he graciously accepted.

The Section has undertaken several activities. First, a few essays on quality control were written by some of the members. Then a translation (into Spanish) of the American Standards Association Z1.1, Z1.2 and Z1.3 was made.

At the same time the Section has been giving elementary courses on quality control to men of several factories and students of the Universidad Autónoma of México.

It is fitting that we are celebrating the 4th anniversary of the foundation of our Club enjoying again the presence of Professor Grant, as our guest.

Ing. Domingo M. López

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*Ed: Apropos of absolutely nothing at all, the following three letters are included strictly for fun. Your editor got quite a chuckle from this by-play and hopes that you will, too.*

Mr. Truman Read
Hamilton Standard Div.
Bradley Field
Windsor Locks, Conn.

Dear Truman:

The following figures will show the number of reservations made prior to each meeting of the Hartford Section and the number of people who actually were present for the meetings from January, 1950, up to and including the May meeting of 1952.

These are the figures which you felt could be used to determine the average expected attendance at our future meetings. . . .

| *Date* | *Reservations* | *Attendance* | *Comments* |
|---|---|---|---|
| February 1950 | 62 | 68 | |
| February 1950 | 75 | 72 | Bad snow storm |
| March 1950 | 102 | 98 | Pratt & Whitney Plant Visit |
| April 1950 | 56 | 69 | |
| May 1950 | 74 | 113 | |
| October 1950 | 73 | 74 | |
| November 1950 | 47 | 62 | |
| December 1950 | Joint meeting—ASTE and ASQC | | |
| January 1951 | 111 | 121 | |
| February 1951 | 57 | 60 | |
| March 1951 | 65 | 68 | Fuller Brush Plant Visit |
| April 1951 | 46 | 49 | |
| May 1951 | 85 | 96 | |
| October 1951 | 95 | 96 | |
| November 1951 | 75 | 90 | |
| December 1951 | Christmas party—everyone present! | | |
| January 1952 | 57 | 64 | |
| February 1952 | 57 | 68 | |
| March 1952 | 58 | 50 | Stormy evening |
| April 1952 | 43 | 67 | |
| May 1952 | 124 | 125 | |

If you're able to prove anything with this information, you're a genius!

Sincerely yours,

/S/ P. M. McDonald, Secretary

Mr. P. M. McDonald
L. E. Waterman Co.
Seymour, Conn.

Dear Phil:

Reference! — It takes a d——n fool, not a genius; whereby I qualify.

Differences between reservations and corresponding attendance plotted either as actual differences or as percentages of reservations do not fit normal or Poisson distribution curves. Any statistical evaluations based on Camp-Meidell or Tchebycheff are of such extent for any usable probabilities as to be useless.

The only conclusions which can be made, all of little value but possibly of interest, follow:

1. Men would rather eat than stay home—in only 3 of 19 cases were more men unable to break away than originally intended to. This indicates that they try hard.
2. Don't argue with your wife in stormy weather—non-fulfillment of intentions as evidenced in 3 of 19 cases occurred under inclement conditions.
3. Since January 1950, the Rockledge Country Club has received payment for 15 meals which the cooks and bartenders ate and for 171 extra meals which they bled from the 1,362 that they originally intended to serve. This 12½% "squeeze" explains why no tip is expected.
4. The best solution: to *stress* the point that each member should come if he makes a reservation in order to save the Society's money, and should make a *reservation* when he *is* coming to assure each diner of more than 87½% calorie return for his monetary outlay. (Uncle Sam is still twice as bad with his income tax percentages.)
5. It's about time for a drink on the house.
6. Next time I will keep my mouth shut even if I do get home later.

Sincerely yours,

/S/ T. W. Read

Mr. George R. Foster
INDUSTRIAL QUALITY CONTROL
6123 Plankinton Building
161 West Wisconsin Avenue
Milwaukee 3, Wisconsin

Dear George:

So that I could open and close the d——n thing at will, I cleaned out one of my desk drawers today. As frequently occurs in such activities, I found a long for-

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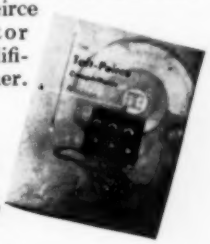

*Write Today for This Bulletin*

**The TAFT-PEIRCE Manufacturing Co.**
WOONSOCKET, RHODE ISLAND

gotten piece of correspondence which turned out to be your property. I return it herewith not in the least abashed. For free, though, I will add some pithy remarks.

The data when put into a frequency distribution looks like it could very well have come from a normal distribution except for that high one which I hereby exclude from all consideration. How as many as 39 Hartford residents got out that night when they assured the little woman that they would not go out is something we in Milwaukee could bear to know. An assignable cause was operating, but good, in Hartford that night. So considering only 18 of the "readings" I state:

1. Five or six (5.84) Hartfordites on the average are successful in eluding home and family on the meeting nights regardless of weather, h——, and high water.

2. Not only that but the odds are 3 to 2 that as many as 14 will make it when the wind is right.

3. The odds against the little woman persuading a Hartfordite to say home when he has firmly decided to go out is about 6 to 1. Either the Hartford male is:

   a. Extremely mulish
   b. Very strong willed
   c. Likes to live dangerously
   d. Just plain foolish

   or the Hartford female:

   a. Employs sweet reason
   b. Is too slow to the front door
   c. Has plans of her own for the evening
   d. Lacks that persuasive appeal

4. Between 8 and 9 of the males are standard deviates (8.35). Not necessarily inebriates, or delinquents, but deviates.

5. I am sometimes happy that we in Milwaukee have not kept similar data on our dinner meetings.

Sincerely,

/S/ L. S. Eichelberger

# Management's Corner

**J. M. JURAN, Editor**

*Correspondence is invited on potential contributions or problems appropriate for discussion in this department. Address your suggestions to:*

*J. M. JURAN*
*195 Beech Street*
*Tuckahoe, N.Y.*

An unusual and significant discussion of quality problems on a national scale is contained in a speech made by Premier Malenkov to the supreme Soviet on August 9th, 1953.

Premier Malenkov's long speech swept across many aspects of the vast Soviet economy, and contained sharp criticism of many facets of the Soviet economy. Of special interest to the American Society for Quality Control are those portions of the speech dealing with the quality of Soviet products and services. The following pertinent portions of Premier Malenkov's speech are quoted from the New York Times of August 10th, 1953, which reported verbatim the text of the speech:

"Many enterprises are still producing articles of an unsatisfactory quality, not meeting the needs of the requirements and tastes of the Soviet consumer. General consumer goods produced by our industry, though as a rule of solid quality, leave a great deal more to be desired in finish and exterior appearance.

"To the shame of the workers of industry, the consumer frequently prefers to acquire goods of foreign production, only because they have a better finish. Meanwhile we have every possibility to produce good-quality and attractive textiles, good-quality smart clothes, and elegant footwear. We have every possibility to provide a good finish to all the goods that serve the satisfaction of the people's requirements.

"The Soviet people are right to demand from us and primarily from workers in industries producing consumer goods, durable, well-finished and high-quality goods. We must answer this demand by action. It is the duty of every enterprise to produce high-quality goods and to care constantly for the durability and good finishing of production. . . .

"We cannot be satisfied with the present volume of retail trade. Moreover, there are serious shortcomings in the organization of the trade itself. In a number of rayons (districts) the trade in all articles necessary for the population has not yet been organized. There are not infrequent cases where a customer wanting to buy some article or other has to go to another town or another rayon. The trade planning organizations must carefully study the demand of the population for various articles. The necessity for an all-sided analysis of the demand and of all the various needs of the population follows from the very essence of Soviet trade. . . .

"Many builders have adopted the evil practice of putting into use new houses with many items incomplete and carelessly finished-off, which reduces the value of these dwellings and provokes the justifiable reproaches of the workers. The task is to improve house building and ensure the definite fulfillment of the Government assignments for the building and repair of houses. . . .

"An example of unsatisfactory leadership of enterprise is provided by the lack of attention of our economic, financial and planning bodies to the problem of reducing production costs. It is well known that production costs are the fundamental indices which characterize the quality of the entire work of an enterprise. . . ."

Naturally, there is a good deal which we in the United States do not know about the Soviet production system and their methods for regulating quality. In the case of consumer goods, the present emphasis seems to be on appearance (finish) rather than on function, although we cannot be sure about

this from the wording of the criticisms. This emphasis on lack of good appearance is in sharp contrast to many criticisms in American factories to the effect that we are too finicky with respect to appearance. There is frequent complaint by our manufacturing departments that sales people overexpand the product line so as to give consumers too wide a range of choice of goods. The result is that only a few percent of the styles will account for a great percentage of the total sales. The remaining sales, amounting to only a small proportion of total sales, embrace a great variety of product styles which undoubtedly are carried at a loss, the extent of the loss usually being unknown.

Beyond the criticism of the breadth of the product line, there is also criticism by manufacturing departments as to the finickiness of sales people in matters of appearance. This department has seen numerous instances in which finish and other appearance characteristics were being perfected to an extent well beyond the sensitivity of the consumer. That is to say, sales people and (following their urging) factory inspectors were enforcing standards of appearance to suit the whims of inspectors or salesmen rather than to suit customers. In actual consumer survey tests it has usually developed that consumers are insensitive to these refinements in appearance. Thereby, the cost of the product has been needlessly increased without any equivalent increase in the value.

The Soviet criticism as to housebuilding has no lack of counterpart in the United States. Material shortages have been, until recently, a prime cause. With the passing of materials shortages, the builders' attempts to shortcut construction or appearance are in the main regulated by the contract between the parties, so that the buyer is by no means helpless.

With respect to functional performance of goods, there have variously appeared in the Soviet newspapers reports of functional failures. The Soviet industries are essentially arms of the government, and in numerous reported instances these failures appear to be regarded as criminal acts on the part of the re-


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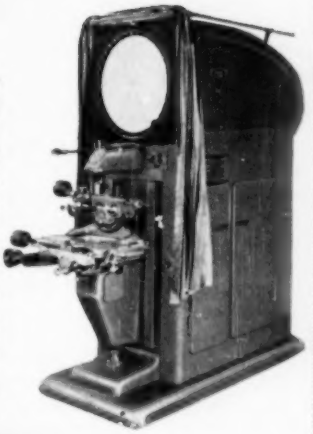

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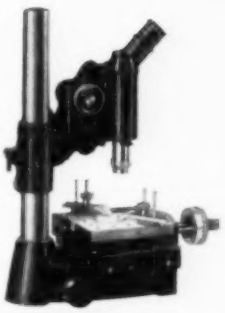

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sponsible officials. Several samples accumulated a few years ago by Reader's Digest included the following incidents:

With respect to the Makeyevka Industrial Combine in Stalin Province. "Out of 7,770 cultivator wheels delivered to the Mariupol Metal Products Factory, all except 217 were defective. Chief Engineer Chvdakov and chief of the technical control department Radchenko, each sentenced to five years' imprisonment." "Coal mines, Stalin Province.—Production of coal containing a high percentage of slate. Manager Anisimov sentenced to five years' imprisonment." "Mechanical Foundry Works in Leningrad, systematic production of poor quality goods.—Chisels sent to other factories found to be unusuable. Adjustable spanners (monkey wrenches) sent out with immovable screws and loose heads. Director Garibyan and Chief Engineer Glinchinov each sentenced to five years deprivation of liberty."

We do not know the details of these quality failures sufficiently to know whether, judged by our own laws, they would be criminal in character. Certainly, in the United States, if an employee of a government enterprise (such as the Post Office) were, as a result of criminal intent, involved in some service failure, he would be subject to criminal prosecution. During World War II there were a number of instances of manufacturers who delivered defective product to the government (who was the customer). In those instances where the manufacturer knew that the goods were defective and none-the-less, either through falsification of records, through bribery, or other criminal means, delivered them to the government, criminal prosecutions resulted. However, this department is not aware of any instance in which the manufacture of defectives *per se* was the subject for criminal prosecution. It was only a basis for rejection or non-payment.

We know all too little about details of the forces which operate on industrial executives in the Soviet Union to judge whether the deficiencies related in Premier Malenkov's speech are fundamental to the Soviet system of economy. Under that system, the product specifications, the breadth of the product line, and the degree of conformance are a problem in broad government planning rather than being left, as in our system, to the molecular action of the free market.

All this adds up to some interesting speculations. With the possible exception of military goods, we have no direct comparison of the design, and the conformance to design, of apparatus made under the two systems of economy. Certainly we are all hopeful that the long-range competition between the two systems will be judged by the comparative standards of living they are able to bestow on their citizenry, rather than by any comparative test of the military apparatus.

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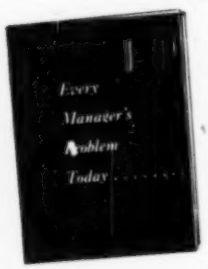


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# Book Reviews

## A. C. Cohen, Jr., *Editor*

*Correspondence and suggestions concerning book reviews should be sent to:*
*Professor A. C. Cohen, Jr.*
*Department of Mathematics*
*University of Georgia*
*Athens, Ga.*

STATISTICAL THEORY WITH ENGINEERING APPLICATIONS
A Hald; John Wiley and Sons, Inc., New York, 1952. 783 + vii pages. $9.00. Reviewed by Blair E. Olmstead, Prudential Insurance Company of America, Newark, New Jersey, and Paul S. Olmstead, Bell Telephone Laboratories, Whippany, New Jersey.

The title of this book, "Statistical Theory with Engineering Applications," has been well chosen. Its "Statistical Theory" does not stop with mathematical statistics (knowledge of differential and integral calculus assumed). In addition it analyzes the limitations inherent in the mathematical assumptions in meeting conditions of application. The main source of "Engineering Applications" is the Portland cement industry, possibly because the book started as a series of lectures for members of the Danish Society for Civil Engineers. Other engineering applications relate to rivets, copper wire, condensers, and aluminum castings. In some cases, the examples were taken from other fields, such as agriculture and medicine.

Although mathematical statistics constitutes the backbone of the book, applications determine almost exclusively the order of presentation and the treatment of material. The first chapter begins by stating: "The theory of statistics is a branch of applied mathematics aiming at a mathematical description and analysis of observations as a basis for the prediction of certain events under certain conditions." The author then considers the occurrence of defects in a manufacturing (or repetitive) process. This leads to the notion of frequency and, when associated with an ideal situation, probability. The calculus of probabilities (mathematics) then provides in Chapter 2 the derivation of such fundamental distributions as the binomial, the multinomial, and the hypergeometric.

In a similar manner, Chapters 3 and 4 consider methods of presenting data. Particular attention is given to empirical distributions of continuous and discontinuous variables with their typical definitions and fundamental properties before taking up in Chapter 5 their counterparts derived from theoretical distributions. Chapter 6 on "Normal Distributions" devotes considerable space to incomplete normal distributions (one or both tails removed) and double-peaked distributions. Chapter 7 on "Skew Distributions" shows procedures for normalization. This is preliminary to devoting the remainder of the book primarily to normal distributions. Chapters 8-12 then present various theorems relating to limits and the more common tests of significance based on means, variances, and ranges.

Chapter 13 on "Statistical Control" discusses "the concept of statistical control and criteria for detecting lack of control, especially for continuous variables." This is an elementary discussion of Shewhart's basic ideas illustrated by considering runs above and below the median, runs up and down, the mean square successive difference, control charts for means and ranges, the concept of a state of maximum control, and the difference between tolerance and specification limits. An important point brought out is that "the validity of any test of significance presupposes a state of sta-


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tistical control." This places an important limitation on the use of statistical tests because we seldom know that such a state exists. In fact, we are often reasonably certain that such a state did not exist at the time our measurements were taken.

Except for the last chapter, the remainder of the book is devoted to special distributions (the variance ratio, the t, the two-dimensional normal, the binomial, the Poisson, and the multinomial), analysis of variance, design of experiments, linear regression analysis, multi-dimensional correlation and regression, and sequential analysis. In each case, emphasis is placed on the limitations inherent in the mathematical assumptions for the test with the caution that these are seldom met in practical applications. The author does not hesitate to use the same set of data to illustrate more than one test. However, he does not make it clear that failure to meet one test is often associated with failure to meet other tests for the same type of assignable cause.

In the final chapter, which is on "The Main Points of a Statistical Analysis," Hald outlines his modification of Fisher's five steps: the planning of the investigation, the specification of the model, the estimation of the parameters and derivation of the sampling distributions of the estimates, an examination of the agreement between the model and the observations, and the real solution of the problem. In so doing, he refers specifically to the various sections of the book where more detailed information is given. In closing, he states: "the theoretical investigations published so far indicate that the tests (of significance) may be highly misleading if the observations are even slightly correlated" and "a satisfactory agreement between the observations and the test hypothesis is not equivalent to a proof of the hypothesis." These are warnings that must be heeded by any user of statistical methods.

Some readers may object to the notation used which differs from the commonly accepted in some instances as explained on page 761. In addition to a detailed table of contents, the book has three indexes: for authors, for subjects, and for symbols and formulas. References to non-European authors are not as complete as might be desired but better than most books of similar origin.

Tables of the distributions used in the tests of significance and certain other tables have been published as a separate volume. Excerpts of some of the tables are included in the book.

This book answers most of the questions raised by engineers about statistical tests, analysis of variance, design of experiments, and regression analysis. It deals principally with the statistics of variables and somewhat casually wtih attributes. It gives limited attention to sequential analysis, growth curves, time series, and stochastic processes. Non-parametric analysis does not even appear in the index. Nevertheless, the book is recommended as a good reference volume for research and development engineers


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**Director of Quality Control, Johnson & Johnson Co.; currently with the Mutual Security Agency**

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**1953** **172 pages** **$4.00**

**SAMPLE SURVEY METHODS AND THEORY**

**By MORRIS H. HANSEN, *Asst. Director for Statistical Standards, U. S. Bureau of Census;* WILLIAM N. HURWITZ, *Chief Statistician, U. S. Bureau of Census;* and WILLIAM G. MADOW, *Chairman, Statistical Research Laboratory, University of Illinois***

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### NEW BOOKS RECEIVED

"The Methods of Statistics," Fourth Edition, by L. H. C. Tippett, 1952. John Wiley and Sons. 395 pp.

"Statistical Tables and Problems," Third Edition, by Albert E. Waugh, 1952. McGraw-Hill Book Company. 242+xiv pp. $3.00.

"Industrial Specifications," by E. H. MacNiece, 1953. John Wiley and Sons. 158+xiii pp. $4.50.

"Statistical Theory in Research," by R. L. Anderson and T. A. Bancroft, 1952. McGraw-Hill. 399+xviii pp. $7.00.

"Statistical Methods in Experimentation," by Oliver L. Lacy, 1953. Macmillan. 249+ix pp.

"Simplified Drafting Practice," by William L. Healy and Arthur H. Rau, 1953. John Wiley and Sons. 156+vii pp. $5.00.

"Design and Analysis of Experiments" by E. F. Lindquist, Houghton Mifflin Co. 393+xvii pp. $6.50.

"Sampling Techniques," by William G. Cochran, 1953. John Wiley and Sons. 330+xiv pp.

"Mathematics and Statistics for Economists," by Gerhard Tintner, 1953. Rinehart and Co. 363+xiv pp. $6.50.

"Sample Survey Methods and Theory," by Hansen, Hurwitz and Madow, 1953. John Wiley and Sons. Vol. I, 638+xxii pp. $8.00. Vol II, 332+xiii pp. $7.00.

"Measurement Techniques in Mechanical Engineering," by R. J. Sweeney, 1953. John Wiley and Sons. 309+x pp. $5.50.

"Introduction to the Theory of Statistics," by Victor Goedicke, 1953. Harper and Brothers. 286+xii pp.

---

# *Bibliography*


**JOSEPH MOVSHIN, Editor**

***Assisted by the Editorial Committee, St. Louis Section, ASQC***


*On matters concerning the Bibliography Department, send correspondence, suggestions, and contributions to:*

*Mr. Joseph Movshin*
*9220 Old Bonhomme Road*
*St. Louis 24, Mo.*

### APPLICATION—CHEMICAL INDUSTRY

CUTS PILOT-PLANT TIME

(Chemical Engineering—v. 60, n. 2, Feb. 1953, p. 322)

A report of using statistical analysis in setting up a new chemical process.

### APPLICATION—ELECTRICAL INDUSTRY

PAPERS ON QUALITY CONTROL

(Trans., IRE—PGQC-2, Mar. 1953)

This second transaction contains a series of articles applying statistical methods primarily to electronic tube manufacturing and testing.

A Variables Double-Sampling Plan.....J. McDermott & L. Bass

Performance Evaluation of "Special Red" Tubes....H. J. Prager

Development of Inspection Manual for Reliable Tubes..E. K. Wimpy

Adoption of Industry Proposals to Subminiature Tube Evaluation.. .....A. J. Heitner

An Engineering Progress Report on Reliable Tubes.....R. E. Moe

### APPLICATION—MISCELLANEOUS

HOW BIGELOW - SANFORD FOUND 2000 YARDS OF "LOST" CARPET, A. G. Klock and C. W. Carter, Bigelow - Sanford Carpet Company

(Textile World—v. 103, n. 6, June 1953, p. 129)

Due to a slipping measuring wheel, 2000 yards of carpet were "lost" between the weave room and warehouse. As a result of a lot plot analysis, a correction factor was applied to each roll with a satisfactory result for the mill and the consumer.

### MANAGEMENT AND PERSONNEL, GENERAL

THE PHILOSOPHY UNDERLYING THE SPECIFICATION MIL-Q-5923 (USAF), Col. J. G. Schneider, Wright-Patterson Air Force Base

(Tooling and Prod.—v. XIX, n. 5, Aug. 1953, p. 8)

Reprint of a talk presented at the 7th Annual Convention, ASQC. Basic philosophy of Air Force procurement is that quality must be built into a product, and secondly, that the contractor is primarily responsible for the control of quality. Specification MIL-Q-5923 describes what must be controlled and leaves the details and responsibilities of its execution to each manufacturer.

PRACTICAL IMPLICATIONS OF THE AIR FORCE QUALITY ASSURANCE PROGRAM, Lt. Col. O. C. Griffith, Wright-Patterson Air Force Base

(Tooling and Prod.—v. XIX, n. 5, Aug. 1953, p. 70)

Reprint of a talk presented at the 7th Annual Convention, ASQC. The Air Force Quality Assurance Program, in addition to assuring the quality of materials supplied to the Air Force, can prove of great benefit to many manufacturers in following the Air Force system of quality control. Gives contractors a pattern for establishing an economic and reliable quality control system in terms of their own operations and products.

QUALITY CONTROL IN COMPONENT MANUFACTURING

(Tele-Tech—v. 12, n. 4, Apr. 1953, p. 112)

The evaluation of quality by consumers' and vendors' lot quality reports are considered. Problems and approaches include:

Laboratory Tests and Inspection
Process Inspection
Sampling Levels
Frequency Distributions (Lot Plot)
Final Inspection
100% Inspection
Customer Complaints

MADISON CONTROLS NYLON THROWING WITH TESTS, INSPECTIONS, OPERATOR TRAINING, Thomas B. Winston, Textile World

(Textile World—v. 103, n. 6, June 1953, p. 96)

Emphasis on control of operators through training and periodical checks. Not SQC.

**INDUSTRIAL MANAGEMENT**

RANDOM RATIO-DELAY, G. Eric McAllister, University of California

(Journ. of Ind. Eng.—v. IV, n. 3, Aug. 1953, p. 15)

The use and need of random numbers to assure random samples in ratio delay is described. Analysis of sample data by analysis of variance is illustrated.

A table of random digits is given.

**QUALITY REPORTING**

QUALITY CONTROL — COMMUNICATING DATA EFFECTIVELY, Lt. Commander W. W. Kauffman, U. S. Naval Gun Factory, Washington, D.C.

(The Tool Engineer—v. 32, n. 3, Sept. 1953, p. 54)

The need for quality information reaching responsible persons is stressed. To do this, quality must be measured in a concrete specific manner; data must be collected, analyzed, and reported; information must be delivered to the proper persons; and follow up must be provided for to assure corrective action. Detailed methods of quality evaluation and reporting are given.


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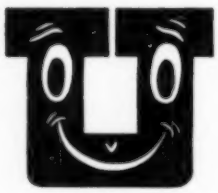

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**THEORY AND APPLICATION—GENERAL**

SCIENTIFIC SAMPLING, Robert K. Mueller, General Manager, Monsanto Chemical Company, Springfield, Mass.

(Modern Plastics—v. 30, n. 8, Apr. 1953, p. 79)

A discussion of Statistical Quality Control, what it is, and examples of its application. Basic records, (the $\bar{X}$ and R control chart) are illustrated.

WHAT IS PROBABILITY?, Rudolph Carnap

(Scientific American—v. 189, n. 3, Sept. 1953, p. 128)

The author discusses basic concepts of probability as preliminary to the calculation and expression of "statistical" and "inductive" probabilities. Limitations and advantages of both concepts are presented. The author's approach to the calculation of "inductive" probability is described.

ELEMENTS OF STATISTICAL QUALITY CONTROL, Lt. Commander, W. W. Kauffman, U. S. Naval Gun Factory, Washington, D.C.

(The Tool Engineer—v. 32, n. 2, Aug. 1953, p. 59)

A description of the basic concepts of statistical quality control. The frequency distribution and $\bar{X}$ and R Chart are illustrated. The organizational function of statistical control is also indicated.

**TRAINING AND EDUCATIONAL**

CONFERENCE ON APPLICATION OF STATISTICAL METHODS (To Pulp and Paper Industry)

(TAPPI—v. 36, n. 3, Mar. 1953, p. 100A)

Full outline of conference at Western Michigan College, June 15-26, 1953.

**STATISTICS**

ELEMENTS OF A MATHEMATICAL THEORY OF PROBABILITY, J. H. Curtiss

(Mathematics Magazine—v. 26, n. 5, May-June 1953, p. 233)

A discussion of some of the underlying philosophy of probability theory. From this, the au-

thor develops the concept of a mathematical theory of probability and the appropriate mathematics.

EQUIVALENT COMPARISONS OF EXPERIMENTS, David Blackwell

(Annals of Math. Stat.—v. 24, n. 2, June 1953, p. 265)

TESTING ONE SIMPLE HYPOTHESIS AGAINST ANOTHER, Lionel Weiss

(Annals of Math. Stat.—v. 24, n. 2, June 1953, p. 273)

GENERALIZED HIT PROBABILITIES WITH A GAUSSIAN TARGET, II, D. A. S. Frazer

(Annals of Math. Stat.—v. 24, n. 2, June 1953, p. 288)

**OPERATIONS RESEARCH**

AN OPERATIONAL ANALYSIS OF TRAFFIC DYNAMICS, Louis A. Pipes, University of California

(Journ. of Appl. Phys.—v. 24, n. 3, Mar. 1953, p. 274)

An operations research (mathematical) development of solutions to problems in traffic dynamics.

TRENDS IN OPERATIONS RESEARCH, Philip M. Morse

OPERATIONAL RESEARCH AS A SCIENCE, Charles Goodeve

A COMPARISON OF STOCHASTIC AND DIRECT METHODS FOR THE SOLUTION OF SOME SPECIAL PROBLEMS, L. H. Thomas

APPLICATION OF OPERATIONS-RESEARCH TECHNIQUES TO AIRBORNE WEAPON SYSTEM PLANNING, Robert A. Bailey

THE DEVELOPMENT OF PLANNING PROCEDURES AT AIR PROVING GROUND COMMAND, David E. Debeau and Robert A. Porter

ANALOGUE COMPUTATIONS OF BUSINESS DECISIONS, William R. Fair

EXPERIENCES IN COMMERCIAL OPERATIONS RESEARCH, Horace G. Levinson

(Journ. of the Operations Research Soc. of Amer.—v. I, n. 4, Aug. 1953)


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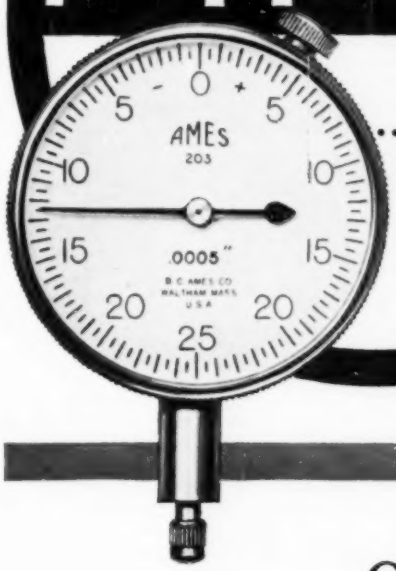


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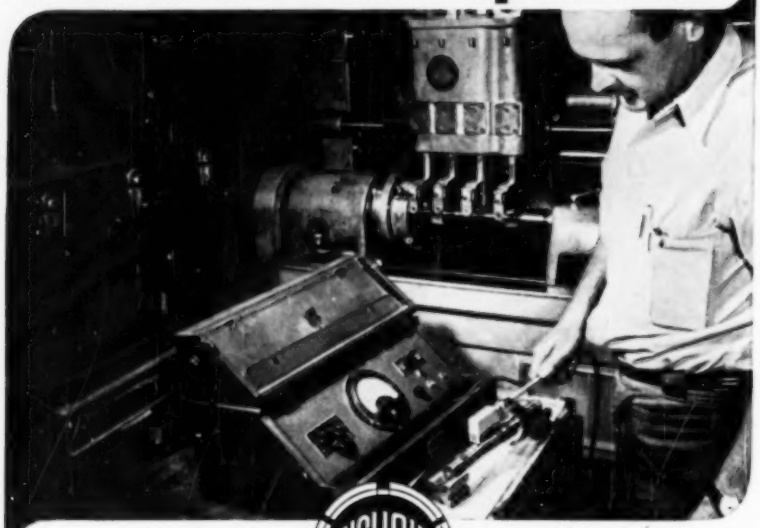

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THE THEORY OF VALUE AND THE SCIENCE OF DECISION—A SUMMARY, Nicholas M. Smith Jr., Stanley S. Walters, Franklin C. Brooks, and David H. Blackwell

LINEAR PROGRAMMING AND PROFIT PREFERENCE SCHEDULING FOR A MANUFACTURING FIRM, A. Charness, W. W. Cooper, Donald Farr and Staff

FAILURE OF COMPLEX EQUIPMENT, Gordon D. Shellard

OPERATIONS RESEARCH AND THE MANAGEMENT CONSULTANT, J. W. Pocock

(Journ. of the Operations Research Soc. of Amer.—v. 1, n. 3, May 1953)

In addition to the above mentioned articles, this publication outlines the program of the 1953 annual meeting of the society and contains abstracts from 35 papers of the program.

**REPORTED—NOT REVIEWED**

NOTE ON THE COMPARATIVE EFFICIENCIES OF SELECTION OF SAMPLING UNITS WITH AND WITHOUT REPLACEMENT, K. Chanda
(Science and Culture—v. 18, Dec. 1952, p. 288)

ON THE APPLICATION OF STATISTICAL CONCEPTS TO THE BUFFETING PROBLEM, H. W. Liepmann, California Institute of Technology
(Journal of the Aeronautical Sciences—v. 19, n. 12, Dec. 1952, p. 793)

T-TEST TECHNIQUES, T. R. Bainbridge

(Modern Textiles—v. 33, Dec. 1952, p. 35)

SOME ASPECTS OF ACCEPTANCE SAMPLING, K. C. Lyon
(Ceramic Age—v. 60, Dec. 1952, p. 24)

MEASUREMENT OF RELATIVE EFFICIENCIES OF COMMERCIAL TELEVISION PICTURE TUBES—A PROBLEM IN STATISTICAL DESIGN OF EXPERIMENTS, W. R. Watson

(Sylvania Technologist—v. 5, Oct. 1952, p. 100)

# Local News Section

*This is the first appearance in IQC of the Section News Department. By this department we hope to bring you more frequent and consequently better service in the matter of section news items. By containing items normally held for the News Supplement, this department will serve as a complement to the News Supplement, and the two together will give you better service since this news will now be available to you on a monthly basis. Ed.*

## ". . . BUT NOT FORGOTTEN"

**ALBANY** The first meeting of this section on Sept. 15 consisted of a plant tour of the Allegheny Ludlum Co. Speaker at the dinner meeting in the evening was D. S. Leckie, Republic Steel, who spoke on "Statistical Applications in the Metal Industry."

**BIRMINGHAM** The first fall meeting of this section was held at the Redmont hotel on Sept. 25. Prof. Dorenfeld, University of Alabama, gave an illustrated talk which was centered around his experiences while serving as a metallurgist and concentrator superintendent for Arizona and Utah non-ferrous mining companies.

**CLEVELAND** The opening meeting of the 1953-54 season was held on Oct. 2 at the Cleveland Engineering Society. Guest speaker for the evening was A. L. Davis, president of ASQC, who talked about the development and future of the Society.

Also at this meeting a report of the Educational committee was presented by its chairman, Wendell H. Abbott. The committee is sponsoring a three-way program of service to the members of the section and to the Cleveland industrial community. This program consists of a correspondence bureau, a speakers' bureau and a short course in statistical methods of quality control.

The purpose of the correspondence bureau is to answer questions about quality control or statistics by instructing the questioner as to where or from whom he may secure a specific answer to his problem. The speakers' bureau is designed to supply to interested industries in the Cleveland area a group of qualified speakers on the subjects of quality control, statistics and related topics. The short course which will consist of six 2-hour sessions was begun during the first week of November.

**DENVER** Ed: Although a digested report on this section's Sept. 14 plant tour of the Alexander Film Co. was available for inclusion in the October Supplement, it was pulled out at the last minute to permit the inclusion of a more complete report here.

In the words of E. J. Flaten, section secretary,

"Occasionally during the regular meetings of the various sections of ASQC, the members and guests are provided with an unusual type of program. . . .

"Of prime interest to the members was the fact that here was a field of application which has received so little attention. This application is not the technical type but rather a combination of clerical and technical.

"It was the feeling of the officers and members of the Denver section that other members of the Society might wish to share in this same experience. . . . it is my feeling that if other members could be aware of this specialized use of quality control, they might find further application in their own plants or offices."

The following is the report of the meeting.

Some 35 members of the section were guests of the Alexander Film Co., Colorado Springs, Colo., for their regular monthly meeting held Sept. 14.

Topic of the meeting, "Film Production and Quality Control," provided members an insight into this unusual application of quality control methods.

The Alexander organization, recognized as the world's largest producer-distributor of film commercials for theatres and television, is currently serving over 27,000 clients throughout the nation and ships over 160,000 feet of film per day.

Needless to say, this mammoth operation requires some very specialized quality control practices which proved to be most interesting.

Following a tour of the 18-acre Alexander studios, the members viewed several Alexander-produced films,

# CALENDAR OF MEETINGS -- NOVEMBER 20 -- DECEMBER 19

| SECTION | DATE | MEETING PLACE | TIME | SUBJECT | SPEAKER |
|---|---|---|---|---|---|
| Albany | 8 | ——— | ——— | SQC in Papermaking and Graphic Arts | Brainerd E. Sooy, Gardner Board & Carton |
| Allentown-Bethlehem | ——— | ——— | ——— | ——— | ——— |
| Baltimore | ——— | ——— | ——— | ——— | ——— |
| Baton Rouge-New Orleans | ——— | ——— | ——— | ——— | ——— |
| Birmingham | ——— | ——— | ——— | ——— | ——— |
| Boston | ——— | ——— | ——— | ——— | ——— |
| Buffalo | ——— | ——— | ——— | ——— | ——— |
| Burlington | ——— | ——— | ——— | ——— | ——— |
| Buzzards Bay | ——— | ——— | ——— | ——— | ——— |
| Carolinas | ——— | ——— | ——— | ——— | ——— |
| Central Illinois | ——— | ——— | ——— | ——— | ——— |
| Chicago | ——— | ——— | ——— | ——— | ——— |
| Cincinnati | ——— | ——— | ——— | ——— | ——— |
| Cleveland | ——— | ——— | ——— | ——— | ——— |
| Columbus | ——— | ——— | ——— | ——— | ——— |
| Dallas-Ft. Worth | ——— | ——— | ——— | ——— | ——— |
| Dayton | 10 | Arlington State Coll., Engr. Bldg. | 8:00 | Metallurgical Process Control | W. H. Sparrow, Chance Vought Aircraft |
| Delaware | 9 | Standard Register Co., Auditorium | 8:00 | Balancing and Randomizing in Experiments | Warren R. Purcell, Rath & Strong |
| Denver | 3 | Hob Tea Room, Wilmington | 6:30 | Installing a Complete QC Program in Industry | Wayne M. Bicklen, Amer. Safety Razor |
| Erie | 9 | ——— | ——— | SQC Projects for Problem Solving | Roy A. Wylie, Micro Switch Div. |
| Evansville-Owensboro | 1 | ——— | ——— | Managing Quality Control to Encourage Quality-Mindedness | A. V. Feigenbaum, General Electric Co. |
| Georgia | ——— | ——— | ——— | ——— | ——— |
| Grand Rapids | ——— | ——— | ——— | ——— | ——— |
| Greater Muskegon | ——— | ——— | ——— | ——— | ——— |
| Harrisburg | ——— | ——— | ——— | ——— | ——— |
| Hartford | ——— | ——— | ——— | ——— | ——— |
| Huntsville | ——— | ——— | ——— | ——— | ——— |
| Indianapolis | ——— | ——— | ——— | ——— | ——— |
| Japan | ——— | ——— | ——— | ——— | ——— |
| Kansas City | ——— | ——— | ——— | ——— | ——— |
| Lansdale | ——— | ——— | ——— | ——— | ——— |
| Lincoln | ——— | ——— | ——— | ——— | ——— |
| Los Angeles | ——— | ——— | ——— | ——— | ——— |
| Louisville | 14 | ——— | ——— | ——— | ——— |
| Metropolitan | ——— | ——— | ——— | ——— | ——— |
| Mexico City | ——— | ——— | ——— | Inspector Training for Quality Control | Arthur Bender, Jr., Delco-Remy Div. |
| Michigan | 11 | Science Hall, Wayne University | ——— | Some Applications in the Printing Industry | O. H. Somers, Western Print. & Litho. |
| Mid-Hudson | ——— | ——— | ——— | ——— | ——— |

| SECTION | DATE | MEETING PLACE | TIME | SUBJECT | SPEAKER |
|---|---|---|---|---|---|
| Milwaukee | — | ——— | — | ——— | ——— |
| Minnesota | — | ——— | — | ——— | ——— |
| Montreal | 25 | ——— | — | The Solution of Production and Inspection Problems by SQC | G. O. Sanders, Canadian Pratt & Whitney Aircraft |
| | 9 | ——— | — | Some Applications of QC in the Tobacco Industry | R. M. Gibb, Imperial Tobacco Co., Ltd. |
| Muncie | — | ——— | — | ——— | ——— |
| New Hampshire | — | ——— | — | ——— | ——— |
| New Haven | 10 | Chamber of Commerce Auditorium | — | Variables Inspection | F. C. Schulze, Hunter Spring Co. |
| N.E. Indiana | — | ——— | — | ——— | ——— |
| Pakersburg | 2 | Chancellor Hotel | 8:00 | Nomographs for Repetitive Calculations | L. G. Mitten, Ohio State University |
| Philadelphia | 30 | Franklin Institute | 4:30 | QC by Narrow-Limit Gaging Procedures | A. B. Mundel, Sonotone Corp. |
| | 11 | Schmidt's Tavern | — | Christmas Party | ——— |
| Pittsburgh | — | ——— | — | ——— | ——— |
| Racine | — | ——— | — | ——— | ——— |
| Rhode Island | — | ——— | — | ——— | ——— |
| Richmond | — | ——— | — | ——— | ——— |
| Rochester | — | ——— | — | ——— | ——— |
| Rock River Valley | — | ——— | — | ——— | ——— |
| St. Louis | — | ——— | — | ——— | ——— |
| Salt Lake City | — | ——— | — | ——— | ——— |
| San Diego | — | ——— | — | ——— | ——— |
| San Francisco Bay Area | — | ——— | — | ——— | ——— |
| Seattle | — | ——— | — | ——— | ——— |
| S. Connecticut | — | ——— | — | ——— | ——— |
| S. Texas | — | ——— | — | ——— | ——— |
| S. Tier | — | ——— | — | ——— | ——— |
| St. Univ. of Iowa | — | ——— | — | ——— | ——— |
| Syracuse | — | ——— | — | ——— | ——— |
| Tennessee | — | ——— | — | ——— | ——— |
| Toledo | — | ——— | — | ——— | ——— |
| Toronto | — | ——— | — | ——— | ——— |
| Trenton | — | ——— | — | ——— | ——— |
| Univ. of W. Ontario | — | ——— | — | ——— | ——— |
| Utica | — | ——— | — | ——— | ——— |
| Washington | 2 | ——— | — | Panel Discussion on Sampling Problems | A. Kramer, E. Houseman, S. Lorber, H. L. Stier |
| W. Massachusetts | — | ——— | — | ——— | ——— |
| Wichita | — | ——— | — | ——— | ——— |
| Worcester | — | ——— | — | ——— | ——— |
| Youngstown | — | ——— | — | ——— | ——— |

and then joined in a general round-table discussion of Alexander production techniques. The speakers were:

Vice president Don M. Alexander, who addressed the group on the evolution of a film commercial from scenario through stage production; Willard Ebeling, laboratory manager, who discussed film processing; Walter Chessman, construction engineer, who spoke on air conditioning and dust control; Elmer Zost, chief chemist, who discussed the various process controls used; Charles Irwin, quality control supervisor, who discussed the problems of film inspection and storage; and James Anderson, production manager, who told about screening for quality and the final acceptance of a film commercial.

*Quality Control Applications at Alexander Film*

1. Sound tract defects
2. Scenario and acting defects
3. Film developing defects
4. Sales appeal defects
5. Control charts on developing and fixing solutions
6. Printing defects

**LINCOLN** The September meeting was held at the Goodyear Tire and Rubber Co. plant at Lincoln. An hour and a half plant tour was held in the afternoon after which the company served as host to the section at a dinner meeting which was held at the Capitol Hotel. Guest speaker for the meeting was E. L. Fay, Deere and Company.

**LOS ANGELES** Approximately 180 members and guests attended the opening dinner meeting of this section which was the annual management night and which was held on Sept. 17.

The meeting chairman for the evening was A. L. Bennett, vice president of Gladding, McBean & Co., who briefly described the role of quality control in the management and sales activities of his company, following which he introduced the speaker L. Grant Hector, vice president of the Sonotone Corp.

Dr. Hector spoke on the topic, "But My Business Is Different." This was a well illustrated talk based on the theme that every business is "different" and that for this reason the quality control man must go beyond the text book to become an effective aid to business.

**MICHIGAN** The Eighth Annual Forum was held at the University of Michigan on Saturday, Sept. 19 with the attendance exceeding 600 persons. Many favorable comments have been received not only about the technical sessions but also about the caliber of the non-commercial-type exhibits and about the fine facilities made available by the University of Michigan.

**MUNCIE** Monday, Sept. 28, marked the opening of another 20-hour course in quality control offered by this section in ten 2-hour sessions on consecutive Monday nights. Ninety-five students from the Eastern Indiana area registerd on opening night. The section is grateful to D. G. Browne, sales manager of the Broderick Company, who is serving as instructor for the course again this year.

**NEW HAVEN** For the opening meeting on Sept. 10 this section welcomed Dr. J. M. Juran, QC consultant, who spoke on, "Getting Staff and Line to Work Together in Quality Control."

Following the meeting was a social hour to permit the members to get acquainted and discuss mutual problems.

**PARKERSBURG** "The electronic age is here and machines are available for the mathematical work so that people are free to do the thinking." These were the opening remarks of a talk at the Oct. 6 meeting by E. K. Amundson, International Business Machines Corp.

Mr. Amundson went on to describe various applications of electronic computers and how they had saved innumerable man-hours of tedious computations. Drawing on his previous experience with the military for several examples, he further stated that electronic computers had graduated from custom built jobs to assembly line production items, and from experimental curiosities in the universities to day-to-day necessities in the commercial offices and laboratories.

Mr. Amundson's talk was preceded by the showing of the IBM sound, color film, "Piercing the Unknown."

**PHILADELPHIA** The first meeting of the fall was held on Sept. 15 at the regular meeting place, the Franklin Institute. In spite of a necessary departure from the regular Friday night meeting time, the meeting was very well attended, which speaks well for the speaker L. E. Seder. Mr. Seder's topic, "Management Problems in the Reduction of Defects," was pointed at top management people.

**PITTSBURGH** Norman R. Moss, Firth Sterling, Inc., presented at the September meeting the paper, "Computing Methods for Multiple Regression." This paper is a collection of methods that the author believes to be most efficient in carrying out the calculations required by multiple correlation.

The testing of coefficients, computing the partial and multiple correlations, the elimination of unimportant variables, and the handling of the method on desk calculators and punch-card computers were discussed.

**RACINE** This section was addressed by Stanley Sherwood, Cadillac Div. of GMC, at its Sept. 10 meeting. Mr. Sherwood presented an interesting approach to "Quality Control as Applied at Cadillac," in which "communications" play the major role.

R. G. Bock, R. G. Bock Engineers, and A. R. Jackson, Allen B. Wrisley Co., teamed up for the dinner meeting of Oct. 1. "Bringing Quality Control from Process Levels to the Desk of Management" was the subject accompanied by applications, slides and charts.

The Racine Extension Div., University of Wisconsin, is again sponsoring a basic course in QC with A. E. Jakel, Supreme Metal Treating Co., as the instructor. The classes which began on Oct. 7, are for 16 two-hour sessions.

**SYRACUSE** On Sept. 29 this section held a dinner meeting at the James Street Methodist Church. William McDonald, chief test engineer of the Easy Washing Machine Corp., spoke on, "Experimental Designs and Balancing and Randomizing in Experiments."

On Sept. 21 this section in cooperation with the Smith Technical High School started its sixth consecutive year of applied quality control courses. The evening classes cover the following three topics: Applied Techniques of Elementary Quality Control, Applications of Sampling Plans and Significance Testing, and Applications of Variance Analysis and Special Topics.

**UTICA** This section started the second season of its educational program during the last week of October. Two innovations were made this year. The first is the offering of two courses in Basic Quality Control at different schools — the Utica Free Academy and the Whitesboro Central School. The second is the offering of an advanced course, Elementary Quality Control, at the Utica Academy. Both courses are being conducted with the cooperation of the Utica Adult Education Program.

**WASHINGTON** At the September dinner meeting this section was addressed by Nicholas Eemos, Statistical Methods Section of the General Engineering Laboratory, General Electric Co., Mr. Eemos presented a thought-provoking discussion of a master plan for company-wide statistical quality control at all levels of production. Mr. Eemos appeared through the cooperation of the General Electric Co. in place of Dr. A. V. Feigenbaum who, at the last moment, was unable to attend as scheduled.

## "... CAST THEIR SHADOWS BEFORE"

**DELAWARE** At the meeting on Dec. 3, Wayne M. Bicklen, American Safety Razor, will talk on, "Installing a Complete Quality Control Program in Industry." The meeting will be held at 7:30 at the Hob Tea Room in Wilmington. Dinner will be at 6:30 prior to the meeting.

**ERIE** Management Night will be held on Dec. 1. A. V. Feigenbaum, Aircraft Nuclear Propulsion Project, General Electric Co., is to be the featured speaker. The title of his talk is "Managing Quality Control to Encourage Quality-Mindedness." A. D. Greene, General Electric Co., will be the program chairman.

**PHILADELPHIA** The November meeting will be held as a joint meeting with the Standards Engineers Society and will feature A. B. Mundel, Sonotone Corp., as the speaker. His topic will be, "Quality Control of Manufacturing Process by Narrow-Limit Gaging Procedure."

The regular Problem Clinic will also meet at 4:30 the same day with Norman Kelsall as the speaker.

Both meetings will be held in the Franklin Institute on Friday Nov. 20; the time for the evening meeting is 8:00.

A gala Christmas party is being planned by Paul Geary. This year's social affair will be held at Schmidt's Tavern on Dec. 11. If you should be in Philadelphia at that time, we extend a cordial invitation to join us in our one purely social activity of the year.

**SOUTHERN CONNECTICUT** Since previous QC courses conducted in Waterbury, Stamford and Bridgeport were so well attended, this section is planning to offer another course this year.

It is also planning to offer a course devoted exclusively to a study and discussion of MIL-STD 105A. Because of the great number of companies in the area working on government contracts, many of the members have evidenced considerable interest in this type of course.

**WASHINGTON** The next dinner meeting of this section will be held on Dec. 2 and will feature the first of the two panel discussions scheduled for the year. The general subject will concern sampling problems and the procedures to solve them.

Members of the panel will be:

A. Kramer, Head of Food Processing
University of Maryland

Earle Houseman, Statistical Consultant
U.S. Dept. of Agriculture

Seymour Lorber, Office Chief of Ordnance
Dept. of the Navy

The panel moderator will be Howard L. Stier of the National Canners Association.

## "AS YE SOW ..."

**EIGHTH NATIONAL CONVENTION** Work on the Eighth National ASQC Convention which is to be held in St. Louis, Mo., June 9, 10, 11, 1954, is progressing successfully. Approximately 50 percent of the program has been arranged and some of the exhibition space has been assigned. The advance registration forms will be mailed at a later date, in time so that those of you who are going to attend can plan your trip to St. Louis.

**PRINCETON CONFERENCE** The Princeton Conference which is held at Princeton University is scheduled for Dec. 4 and 5 this year. Complete information about the program, registration costs, etc., can be obtained from F. Bruce May, Johnson & Johnson, New Brunswick, N.J.

## SIGNIFICANT DIFFERENCES

Wharton F. Keppler has recently left his position as SQC specialist with the Central Air Procurement District to go to the U.S. Naval Ordnance Test Station at

China Lake, Calif., where he is now analytical statistician.

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Charles D. Ferris, past chairman of the Southern Connecticut section, was recently appointed quality control manager of the Mohawk Carpet Mills, Inc. Mr. Ferris is now located at the main office in Amsterdam, N.Y.

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The San Bernardino subsection of the Los Angeles section is continuing to grow. They have planned many fine programs and have already held several meetings. Due to the large area served, the meetings are held in different localities each month.

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The Philadelphia section has several items to report. In the first place, three of its members are serving as instructors for SQC courses in the local schools. Edward B. Haden and Richard M. Jacobs are teaching in the Evening Extension Division of the Graduate School of Villanova College and Peter P. Graziano is on the faculty at Temple University School of Business and Public Administration.

In the moving-up department, Allen R. Crawford was recently appointed assistant professor of applied statistics at Rutgers University, and Joseph E. Beezer, past chairman of the section, was recently promoted from quality control manager to plant manager of RCA's Moorestown Plant.

In the public relations department, Richard M. Jacobs, publicity chairman, reports that a letter of appreciation was sent in the name of the Philadelphia section to the various companies with which the officers and committee-men are connected. This letter informs the companies that their employees have been selected to serve the Society and thanks the companies for the help which they contribute to the Society through their employees. Seventeen letters were sent out to companies in the area, and at the time this went to press nine very fine replies had been received.

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An excerpt from "The Chairmans Corner" by Dave Archibald, chairman of the San Diego section:

"I had the opportunity to visit a large industrial concern while in the East and witnessed some quality control procedures that convinced this writer that quality control problems are generally universal and that most difficulties we encounter have also been experienced by someone else in our profession. A Society such as ours is invaluable under such circumstances if we will but avail ourselves of the opportunities provided. If you haven't already renewed your membership, please give the utmost consideration to reaffiliation now."


# QUALITY CONTROL ENGINEERS

**Here's an invitation to investigate this excellent opening . . .**

## THE JOB

Administrative capacity. Will be required to develop, plan and inaugurate additional quality control programs in large electronics plant and see that they are effectively carried out. Excellent starting salary commensurate with experience.

## BENEFITS

Located in beautiful suburban area just outside Baltimore. Good schools, excellent shopping facilities, ample housing availabe. Modern, air-conditioned plant, ideal working conditions. Paid vacations and holidays, group insurance, many other employee benefits.

## REQUIREMENTS

Prefer man with B.S. degree, with training in statistical quality control.
Should have approximately 5 years experience in field and be between 25 and 45.

Send resume of experience to:
MR. L. H. NOGGLE
Dept. Q.

**Bendix Radio**
TOWSON, MARYLAND

# American Society News

### OPERATING COMMITTEE MEETING

On Saturday, July 25, 1953, the Society's Operating Committee met at the Hotel Rochester, Rochester, N.Y. Numerous details that had come up since the last meetings of Society groups in Philadelphia at the end of May were discussed with a view to making appropriate recommendations to the Executive Committee. The status of work and comments received from each of the several national committees were reported by the responsible Society officer.

### EXECUTIVE COMMITTEE MEETING

At the kind invitation of the Michigan Forum, the Operating and Executive Committees met at the University of Michigan in Ann Arbor on Saturday and Sunday, Sept. 19 and 20, 1953. All members of both committees were present except Max Astrachan who was temporarily in Korea.

Tentative plans for the numerous official Society activities at the St. Louis convention were discussed. It was decided that at the Annual Meeting, in place of the oral summary reports of the officers and committees, there will be available a supply of duplicated reports for those attending.

Three new sections were admitted to the Society. Their names and local officers follow:

**72 Burlington (Vt.)**
Chairman: Chester Gadzinski, General Electric Co., Burlington.
Vice Chairman: Charles F. Pearson, National Carbon Div., St. Albans.
Secretary: Richard W. Hooley, University of Vermont, Burlington.
Treasurer: John L. Rogers, Pal Blade Co., Plattsburg, N. Y.

**73 Baton Rouge-New Orleans (La.)**
Chairman: P. F. Boyer, Louisiana State University, Baton Rouge.
Vice Chairman: E. J. Newchurch, Esso Standard Oil Co., Baton Rouge.
Secretary: M. E. Hayman, Johns-Manville Products Corp., Marrero.
Treasurer: E. N. Martin, Sr., Godchaux Sugars, Inc., New Orleans.

**74 Harrisburg (Pa.)**
Chairman: W. H. Coughlin, Thompson Products, Inc., Harrisburg.
Vice-Chairman: M. C. Kieffer, Olmsted Air Force Base, Middletown.
Secretary: Richard W. Arter, Thompson Products, Inc., Harrisburg.
Treasurer: C. S. Charles, Jr., Aircraft-Marine Products, Inc., Harrisburg.

The new membership application blanks which are currently being prepared will contain provision for indicating the appropriate business activity classification of the applicant. The classifications which are being included on the blanks were obtained from a standard list prepared by the Membership Roster committee. This is the first step in a move to classify the entire Society membership so that a cross-index of business activity can be published in the yearbook. The standard categories will also be marked on the member's addressograph plate making readily available the drawing off of special lists in any one or more classifications for the use of the Membership committee, the Technical committees or Divisions, Publications Office, etc.

A recommendation to change the name of the Section Management Award to the "Presidential Award for Section Management" will be presented to the Board of Directors at its November meeting in Providence, R.I. As a start toward setting up an operating fund for this award, $200 was donated by the Midwest Conference Board.

Approved was the appointment of the following individuals to the Nominating committee:

Simon Collier, *Chairman*
Clarence R. Burdick
Marsh B. Gwynn
Wyatt H. Lewis
August B. Mundel
A. C. Richmond
Leonard A. Seder

In accordance with the constitution, this committee ". . . shall receive and consider such suggestions with regard to possible or desirable nominees for the several Society offices as any member or group of members may desire to offer—such suggestions being sent to the chairman or to the secretary of the committee." Since the committee will be

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aiming to complete its work of selecting a suitable slate of nominees to present to the Society before Jan. 1, 1954, recommendations should be sent to Mr. Collier at once.

A resolution formalizing for the first time in officially recorded form the composition, duties, responsibility and authority of the General Convention committee was approved.

The report of the Section Representation committee on redistricting the country for administrative purposes was discussed and approved with some changes. This revised report will be submitted at the November Board of Directors meeting.

The Society's films have been shown eight times during the months of July and August, there having been 17 requests for them since July 1. Expected to be available soon is the film, "Quality Control in the Cleveland Area." The Southern Tier section has undertaken as a special project for this year the work of preparing the script and organizing the presentation of the colored slide film, "Basic Elements of a Good Quality Control System."

The Dayton section's special project has been to take care of all the local and publicity arrangements for the Aircraft Technical Committee's Quality Control Conference which was held at the Dayton-Biltmore Hotel, Nov. 16 and 17. The committee's Aircraft Supplement No. 1 was distributed to all registrants at the conference and will soon be mailed free to everyone who requested a copy prior to Sept. 1, in accordance with the announcement which was published in the June News Supplement and July IQC. Requests for the Supplement are still coming in and will be filled at $1.50 per copy as long as the supply lasts.

A resolution, approved in principle, was made to the effect that there be established an overall staff committee to consist of the chairmen of the present technical committees and divisions plus representatives from fields of activity not otherwise represented.

To investigate and recommend the objectives and plans for a Business Operations Technical Committee, a stering committee was appointed with Dale L. Lobsinger as chairman.

Several items of business which were discussed by the Executive Committee and which are now nearing the approval stage are a manual on personnel policies, the establishment of a national employment committee, and the Division By-Laws.

The society also gratefully accepted contributions from the Chicago section of $75 for the Brumbaugh Award Fund and $25 for the Shewhart Medal Fund, and the personal contribution from Julian H. Toulouse of $25 for the Brumbaugh Award Fund.

Of paramount interest to each member are the comparative national membership figures as of Sept. 30 for last year and this:

| *Sept. 30, 1952* | *Sept. 30, 1953* |
|---|---|
| 3639 | 3879 |

Although the increase of 240 members over the same time last year has its encouraging aspects, it does not mean that effort can be relaxed. The fact is that the 3879 figure is considerably below the anticipated figure for the first quarter of this year. As a matter of fact, in comparison to previous years' activities,


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the first two months were extremely poor and only because of an extremely good month in September were we able to make this showing. Certainly a continued vigilance and effort are indicated if we are to come up to our anticipated growth for this year.

### NOMINATIONS FOR THE 1953 SHEWHART MEDALIST

The Shewhart Medal committee has opened nominations for the next medalist to whom the award will be made at the St. Louis Convention of the Society in 1954. The committee has expressed the considerations on which nominations should be based as follows:

> "Outstanding contributions to the science of quality control, successful promotion and managment of quality control programs, and service to the art and to the Society are among the factors which should be considered in selecting nominees."

Nominations for this award are invited from members of the Society groups of members or sections. Membership in the Society is not required for eligibility and it is desirable that nominations be made with broad national and international scope rather than on a sectional basis.

Responsibility for selecting a medalist rests with the Shewhart Medal committee but the committee welcomes wide-spread interest and assistance and urges the membership to name suitable candidates before the January 31, 1954 deadline date for such nominations. The names of all nominees should be sent to the chairman of the Shewhart Medal committee:

Maj. Gen. Leslie E. Simon
Office Chief of Ordnance
Washington 25, D.C.

### FELLOWS

On the recommendation of the Examining Committee the following men have been elected Fellows of ASQC:

**W. A. MacCrehan, Jr.**
The Lord Baltimore Press
Baltimore, Maryland

**C. A. Stines**
National Cash Register Co.
Dayton, Ohio

**B. L. Lubelsky**
Naval Ammunition Depot
McAlister, Oklahoma

**E. C. Harrington, Jr.**
Monsanto Chemical Co.
Springfield, Mass.

**A. G. Klock**
Bigelow-Sanford Carpet Co.
Thompsonville, Conn.

**N. G. Meagley**
Willys-Overland Motors
Toledo, Ohio

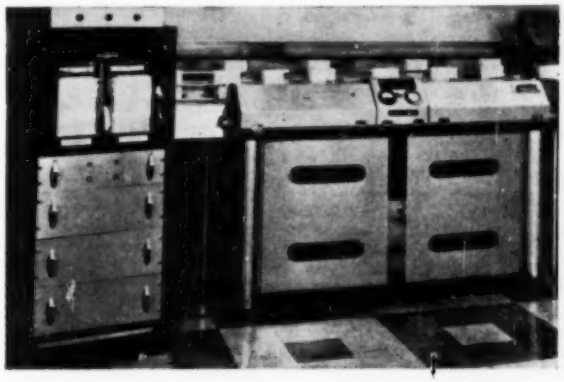
**W. J. Masser**
General Electric Co.
Philadelphia, Pa.

**A. R. Crawford**
Rutgers University
New Brunswick, N. J.

### MEMBERSHIP CORNER

Only by gaining new members can a section, and the Society, grow and prosper. The section that wants to progress, therefore, makes the gaining of new members an all-season activity.

Where can new members be found? The same companies and

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MEASURE your entire production output—eliminate doubtful "sampling". The SELECTROL checks *every* unit produced. It automatically weighs, classifies, sorts, and records.

COMPARE every unit produced and learn immediately the range and average of units *as they are produced*. The Average and Range Control Plotter records each production unit as it flows over the SELECTROL.

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industries which now have members are excellent sources for new members. As new people are assigned to quality control work they become prospects for membership. Encourage each member of your section to refer new prospects to your membership committee. It is a favor to the new man to put him in contact with the Society which is interested in his professional advancement.

Another source of members consists of those companies or industries which should be using modern quality control methods, but are not. This is the great, undeveloped potential. To secure any appreciable number of members, it is necessary first to gain reception for the idea of modern quality control. Your section should devote some of its activity to programs designed to stimulate the interest of the non-user—to show him how his company can benefit.

Tangible leads are needed, however, to sign up new members. Each section has its sources of leads. Look for rosters of non-members attending meetings and special events, for a non-member mailing list, for names of students attending courses in quality control subjects. Urge your members to refer names of interested business and personal acquaintances to your membership committee.

The next step is to contact your prospects. A letter explaining the advantages of membership is a convenient and effective means of making the first contact. A form letter similar to the example given in the Membership Manual is recommended. The important point is to get your message to *all* potential members. Include a copy of your year's program and application blanks. Make it attractive and easy for your prospective members to become members.

Finally, maintain a follow-up system. A personal follow-up by telephone or visit gives the prospect an opportunity to ask questions on which he may have doubts and gives the membership committee an opportunity to answer objections.

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PhD in plant-animal science and statistics desires position as beginner in statistical quality control in any field with good potential. Please reply to Box 10C3 at the above address.

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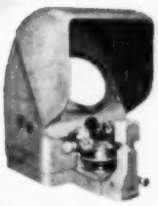

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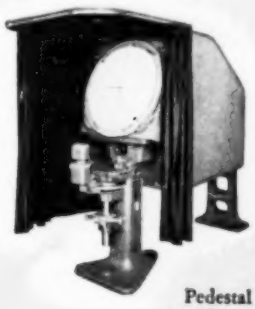

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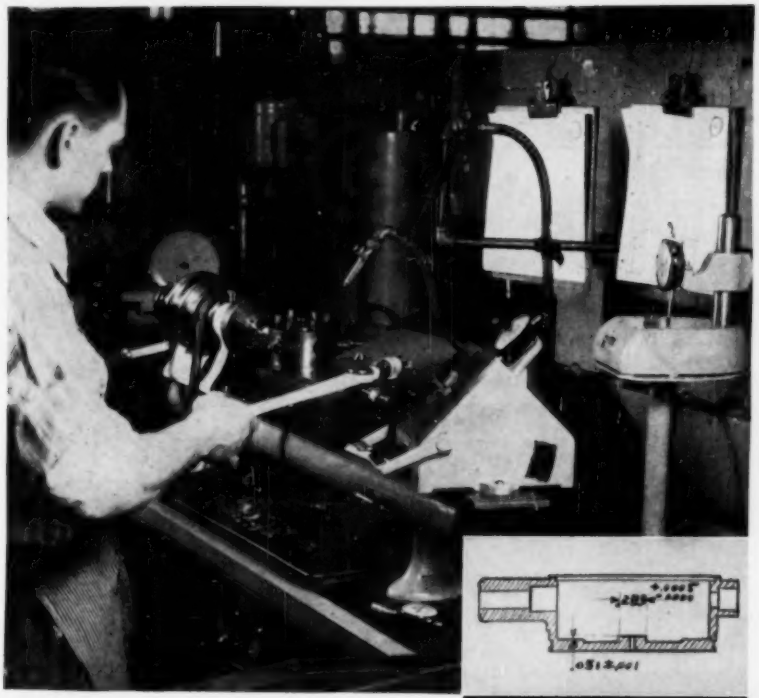

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